The Feasibility of Optimization for Online News Popularity Prediction

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Abstract

The internet has expanded into an immense data ocean and has become the main resource of how people absorb information on a daily basis. ABC evening news viewership grew 16% to 7.6 million viewers in 2020, following an 11% increase in 2019. CBS evening news viewership grew 7% to about 5 million viewers in 2020, while NBC viewership rose 8% to 6.5 million (Pew Research Center, 2021). In this paper, we analyze 39,644 online articles using a broad set of extracted features (e.g., number of words in the title, contents, keywords, polarity) to find the optimal machine learning model for predicting number of article shares. The optimal performance was provided by stochastic gradient boosting with 100 regression trees, maximum interaction depth of 5, shrinkage of 0.1, and minimum node observations of 10.

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Introduction

As the trends for Machine Learning (ML) and Artificial Intelligence (AI) have gradually become more and more popular in the last decade or two, Intelligent Decision Support Systems (IDSS) has drawn attention of all industries to help with decision making especially at the online platforms. While the resources for online information can be overwhelming, we could help with increasing the exposure and provide solutions to upscale the popularity of online news. Given a large set of data with different features and our target variable "shares", we would like to train a machine learning model to provide an optimization for "shares" of the online news before they are published to maximize the exposure. While Fernandes et al. (2015) frame the prediction objective as a classification problem (popular vs. not popular), we instead approach it as a regression problem (number of shares). The final model would aim for the lowest Root Mean Squared Error (RMSE) with the highest R-squared value to ensure we can achieve the highest accuracy on the predictions while considering the Bias-Variance Tradeoff. RMSE is interpreted as how far, on average, the residuals are from zero (Kuhn, 2008).

Exploratory Data Analysis

The dataset contains 39,644 samples and 61 variables. One of the variables, "url," was discarded because it is a sample identifier, not a predictor. The target variable, "shares," ranges from 1 to 843,300, has a median of 1400, and a mean of 3,395. It is heavily right-skewed, as shown in Figure 1. The natural logarithm transformation was applied to "shares" to correct its skew and facilitate modeling (Feng et al., 2014). While the log version still has outliers, its distribution is much more symmetrical and was used as the modeling target (See Figure 2).

Figure 1

Shares Distribution

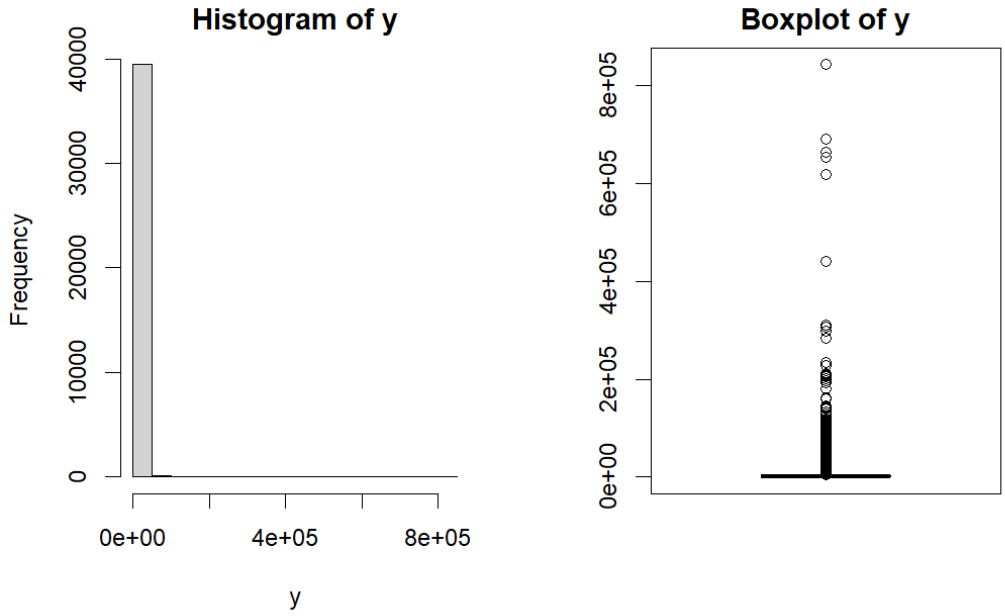
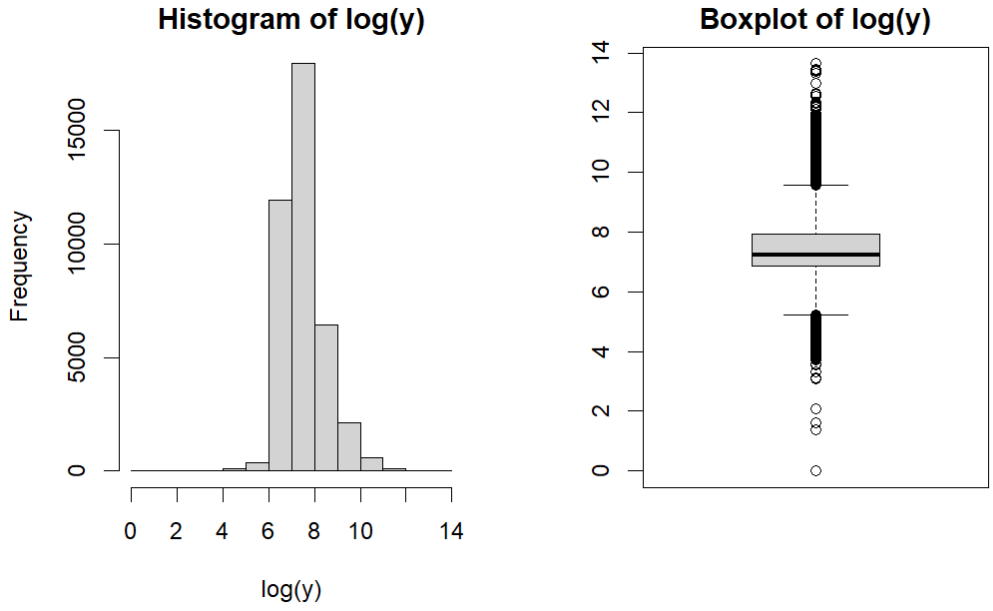


Figure 2

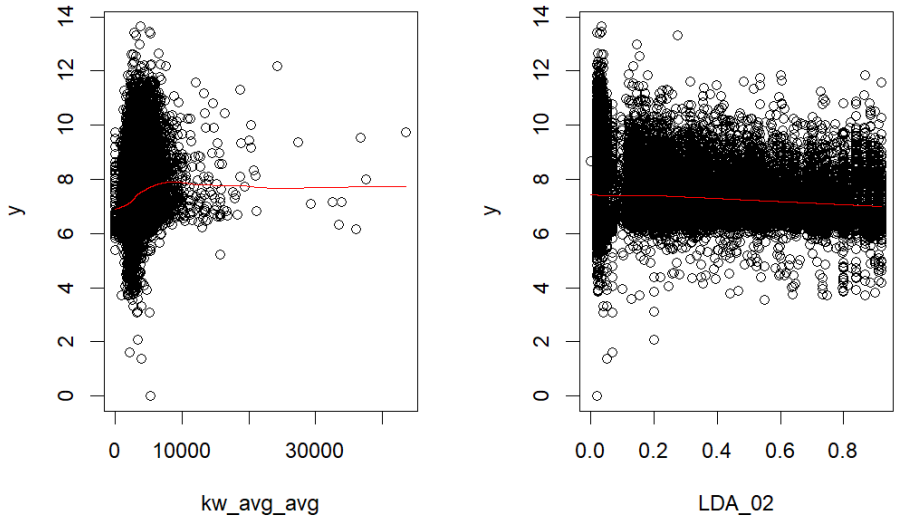
Log of Shares Distribution



The Pearson correlation coefficient was calculated between each predictor and the target. “kw_avg_avg” and “LDA_02” are the predictors most positively and negatively correlated with the target, with coefficients of 0.22 and -0.17, respectively (see Figure 4). This suggests a lack of strong linear relationships between the target and predictors.

Figure 4

Strongest Linear Target-Predictor Relationships



Note. The red line in this figure represents the LOWESS smoothing with a span of 0.66, a delta of 0.01, and 3 robustifying iterations.

Data Wrangling and Pre-Processing

There are no missing values in the dataset, so imputation was not needed. All outliers were retained because they are not the result of incorrect data and therefore provide useful information about the prediction target: news article virality. Each predictor was checked for near-zero variance, as defined by having 10% or fewer unique values out of the total number of samples or having the ratio of the most common value to the second most common value by

greater than or equal to 95:5. “kw_min_max” was the only predictor that met these criteria and was removed to avoid model failure (Kuhn, 2008).

The predictors were also checked for multicollinearity, which can result in unstable regression coefficient estimations (Daoud, 2017). The predictors were split into binary and non-binary sets and their pairwise correlations were calculated (See Figure 5 and Figure 6). Predictors that contributed to correlations greater than or equal to 0.7 were removed. For binary predictors that included the “is_weekend” indicator, which intuitively has a large correlation with the “weekday_is_saturday” and “weekday_is_sunday” flags. “weekday_is_sunday” was also removed to avoid the dummy variable trap where each dummy can be perfectly predicted by the others (Fernandes, Solimun, & Nurjannah, 2022). The data channel flags, in contrast, do not always sum to one and therefore do not fall into that trap. 12 of the non-binary predictors were also removed using the same 0.7 threshold. 44 predictors remained after this filtering process.

Figure 5

Binary Predictor Correlations

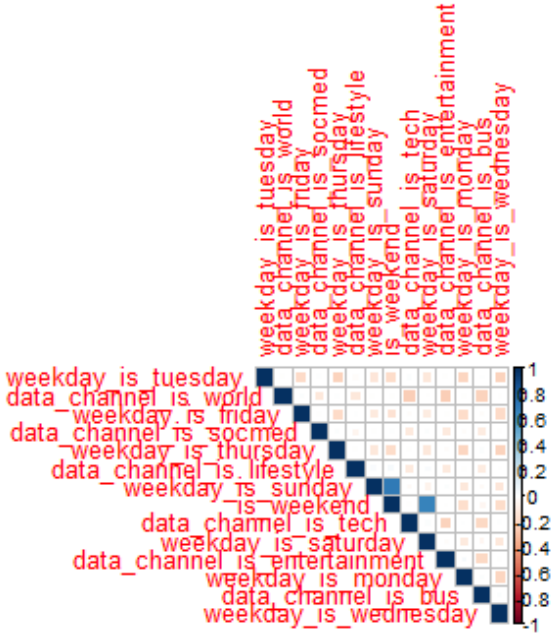
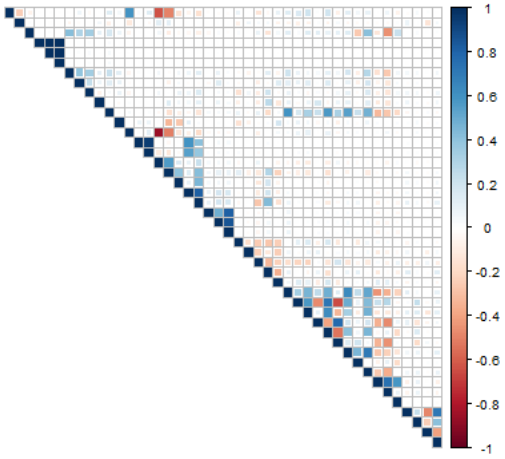


Figure 6

Non-Binary Predictor Correlations



Data Splitting

We used stratified sampling to assign 80% of the data for training, and the remaining 20% for testing. We chose stratified sampling to ensure the target distribution was consistent across training and testing (Menon, 2020). We then split the training set into 10 folds for cross-validated model tuning (Sanjay, 2020).

Methods

Model Strategy

The logarithm of the number of news article shares is a numeric variable, so predicting it is a regression problem. We wanted to try a variety of regression models, both in terms of type and complexity, because we did not know how much information was present in the dataset. The candidates represented linear, non-linear, and tree-based models. The linear models included elastic net regression (enet), principal component regression (PCR), and partial least squares regression (PLS). K-nearest neighbors (k-NN) was the only non-linear model because support vector machines (SVM) and neural networks were too computationally expensive for our limited

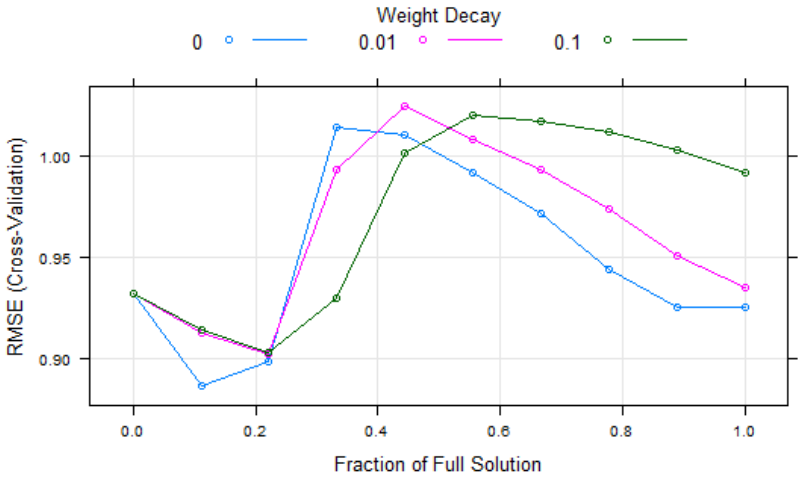
resources. Classification and regression tree (CART) and stochastic gradient boosting machines (GBM) were the tree-based candidates.

Model Tuning and Validation

Each model was hyperparameter tuned using 10-fold cross validation on the training set. All training, validation, and test sets were independently centered and scaled to facilitate modeling. Elastic net was chosen as the first linear model because it combines the ridge and lasso penalties, which each tend to outperform non-penalized ordinary least squares (Zou & Hastie, 2005). Elastic net was tuned on hyperparameters alpha (fraction of full solution) and lambda (shrinkage or weight decay). The advantage of using Elastic net is that regularization is very effective as the ridge-type penalty has the feature selection of a lasso penalty method. We had 10 values of alpha between 0 and 1, and values 0, 0.01, and 0.1 of lambda were evaluated (See Figure 7). Alpha of 0.111 and lambda of 0 yielded the best performance, with a cross-validated RMSE and R-squared of 0.886 and 0.097, respectively.

Figure 7

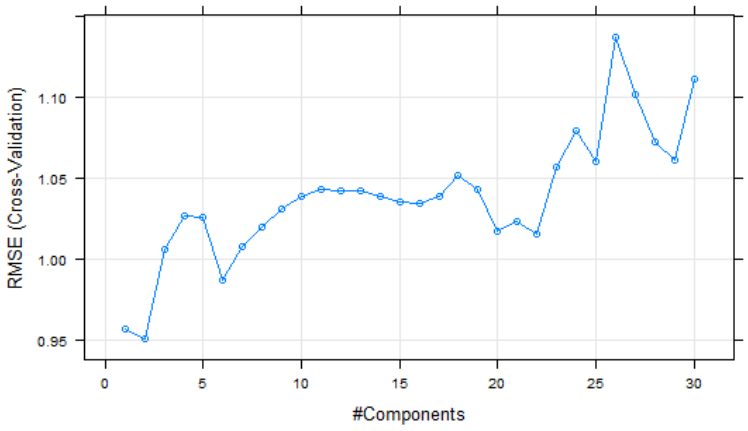
Elastic Net Hyperparameter Tuning



Pre-processing predictors via PCA prior to performing regression is known as principal component regression (PCR) (Massy 1965); this technique has been widely applied in the context of problems with inherently highly correlated predictors or problems with more predictors than observations (Kuhn, 2008). We chose the PCR model as it would give us a good understanding whether a predictive relationship is present by determining whether the variability in the predictor space is not related to the variability of the response. PCR was tuned on the number of principal components, ranging from 1 to 30 (See Figure 8). The best tune used two principal components and yielded a cross-validated RMSE and R-squared of 0.951 and 0.014, respectively.

Figure 8

Principal Component Regression Hyperparameter Tuning

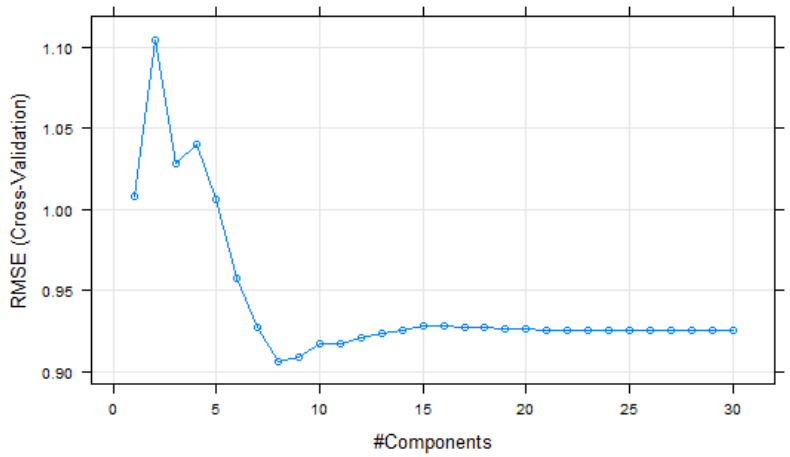


The Partial Least Squares (PLS) model is very similar to the PCR model but instead tries to find a linear regression model by having the predicted and observable variables projected into a new space. We chose the PLS model so that we can compare it to the PCR model results. The main difference between the two is that PCR focuses on variance while reducing the dimensionality while PLS focuses on covariance. PLS helps reduce dimensionality of the

correlated variables and model the underlying information of those variables.PLS was also tuned on 1 to 30 components (See Figure 9). 8 components was the best tune with an RMSE and R-squared of 0.906 and 0.092, respectively.

Figure 9

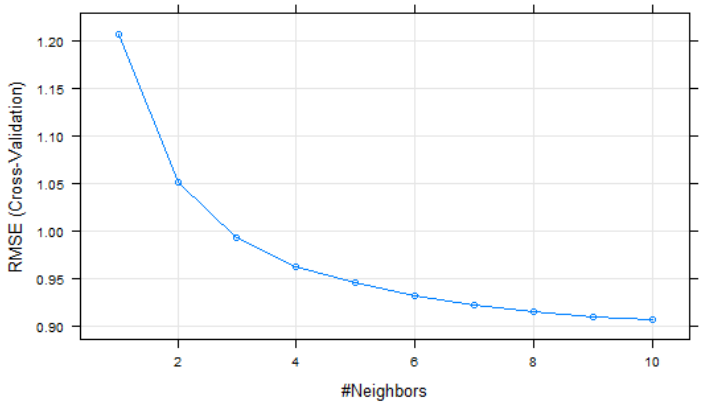
Principal Least Squares Hyperparameter Tuning



Similar to the regression context, k-NN for classification predicts a new sample using the K-closest samples from the training set. “Closeness” is determined by a distance metric. We chose this model because of the fact that the training portion of this model is done relatively quickly and due to the fact it is very simple to explain and implement. For K-NN, 1 to 10 neighbors were assessed, and 10 performed the best (See Figure 10). 10-NN resulted in an RMSE and R-squared of 0.906 and 0.082, respectively.

Figure 10

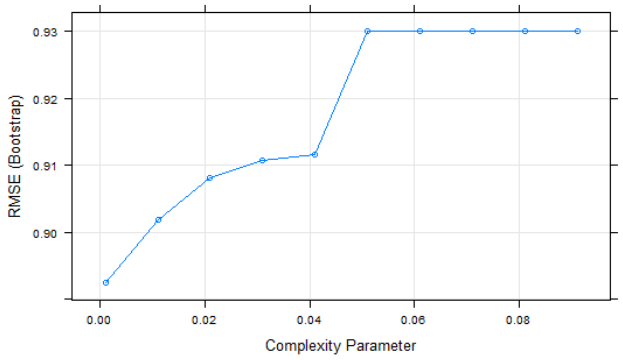
K-Nearest Neighbors Hyperparameter Tuning



CART was tuned along 10 complexity parameter values between 0.001 and 0.091 (See Figure 11). The complexity parameter of 0.001 returned the best RMSE and R-squared values of 0.892 and 0.090, respectively. The complexity parameter is a penalty proportional to the size of the tree (Camdeviren et al., 2005). The cross-validated RMSE only increased as the complexity parameter increased, meaning more complex trees performed consistently better than less complex ones. This suggests the predictive patterns in the dataset may be too complex for simple models to learn.

Figure 11

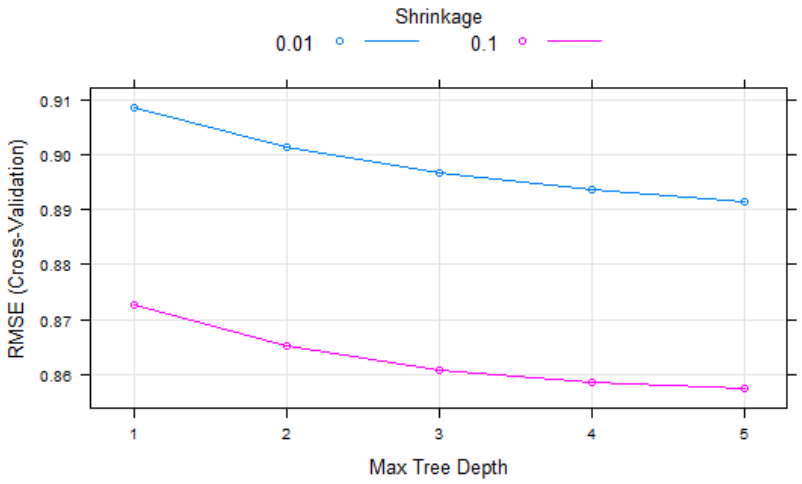
CART Hyperparameter Tuning



GBM was tuned across values of shrinkage 0.01 and 0.1 and interaction depth, or max tree depth, 1 to 5 (See Figure 12). Number of trees and minimum number of observations in node were held constant at 100 and 10, respectively. Shrinkage of 0.1 and interaction depth of 5 resulted in the best tune, yielding RMSE and R-squared values of 0.857 and 0.155, respectively. These tuning results corroborate those of CART, showing that more complex trees consistently outperform simpler ones.

Figure 12

GBM Hyperparameter Tuning



Results

This is a regression problem so the objective is to predict as closely as possible the target values of new data. Test RMSE was used as the primary performance metric because it penalizes predictions that are far from the actual unseen target values. R-squared was also considered, as it represents the proportion of target variance captured by the model. The baseline model simply always predicts the mean of the training target, 7.47, which results in a test RMSE of 0.923. All of the tuned candidate models beat this benchmark (See Table 1). GBM, however, achieved the lowest test RMSE of 0.848 and was therefore chosen as the final model. Its predictions are quite

symmetrical, but its residuals are slightly right-skewed (See Figure 13). The residual distribution shows that the model tends to slightly overestimate the target, but when it does underestimate it does so more dramatically.

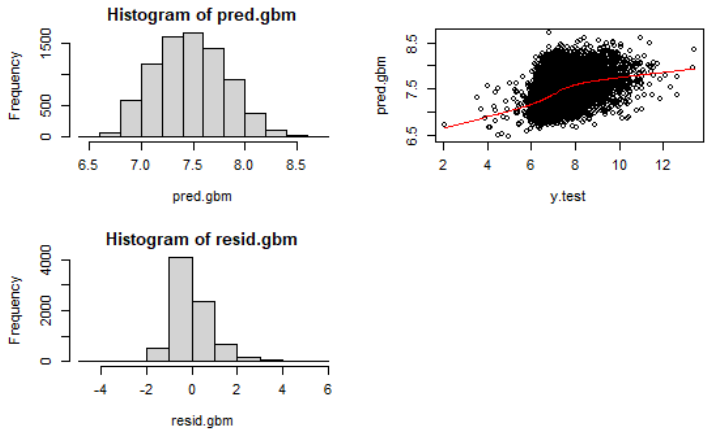
Table 1

Performance of Tuned Models

Model	RMSE CV	RMSE CV SD	RMSE Test	R-squared CV	R-squared CV SD	R-squared Test
enet	0.886	0.022	0.874	0.097	0.017	0.104
PCR	0.951	0.084	0.915	0.014	0.006	0.017
PLS	0.906	0.075	0.874	0.092	0.029	0.104
k-NN	0.906	0.019	0.902	0.082	0.01	0.046
CART	0.892	0.007	0.877	0.09	0.007	0.097
GBM	0.857	0.018	0.848	0.155	0.01	0.156

Figure 13

GBM Test Predictions and Residuals



Discussion

According to the final model, the variables most predictive of article shares are "kw_max_avg," "self_reference_avg_sharess," "timedelta," and "kw_min_avg." "kw_max_avg" and "kw_min_avg" represent the popularity of the article's keywords on Mashable, "self_reference_avg_sharess" represents the popularity of the other Mashable articles it links to, and "timedelta" is the number of days since the article was published (Fernandes et al., 2015). The model is therefore saying that the popularity of an article's keywords and related articles, and how long ago it was published, are the most important factors for predicting how many times it will be shared. This is intuitive because one would expect articles related to trending topics to be more popular.

While the final model outperforms the baseline test RMSE, the tuning process suggests further improvement is possible. Greater tree depth consistently improved the cross-validated RMSE, but tuning was halted at 5. Furthermore, only two shrinkage values were tested, so there could be opportunity for improvement in that dimension as well. Finally, the number of trees was not tuned and simply set constant at 100. These decisions were due to computing constraints. Future research should leverage greater computing resources to explore a larger GBM hyperparameter space. More computing power and memory would also provide the opportunity to test more complex nonlinear models like SVM and neural networks, which may outperform GBM.

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Appendix

ADS 503 Team 4: Predicting Article Shares

Code

Load Data

Hide

```
df <- read.csv("Datasets/OnlineNewsPopularity.csv")
dim(df)
```

```
[1] 39644    61
```

Hide

```
summary(df)
```

```
     url                timedelta     n_tokens_title n_tokens_content n_unique_tokens    n_non_stop_words    n_non_stop_unique
_tokens   num_hrefs      num_self_hrefs       num_imgs
 Length:39644       Min.   :  8.0   Min.   : 2.0   Min.   :   0.0   Min.   :  0.0000   Min.   :   0.0000   Min.   :  0.0000
Min.   :  0.00   Min.   :  0.000   Min.   :  0.000
 Class :character   1st Qu.:164.0   1st Qu.: 9.0   1st Qu.: 246.0   1st Qu.:  0.4709   1st Qu.:   1.0000   1st Qu.:  0.6257
1st Qu.:  4.00   1st Qu.:  1.000   1st Qu.:  1.000
 Mode  :character   Median :339.0   Median :10.0   Median : 409.0   Median :  0.5392   Median :   1.0000   Median :  0.6905
Median :  8.00   Median :  3.000   Median :  1.000
                    Mean   :354.5   Mean   :10.4   Mean   : 546.5   Mean   :  0.5482   Mean   :   0.9965   Mean   :  0.6892
Mean   : 10.88   Mean   :  3.294   Mean   :  4.544
                    3rd Qu.:542.0   3rd Qu.:12.0   3rd Qu.: 716.0   3rd Qu.:  0.6087   3rd Qu.:   1.0000   3rd Qu.:  0.7546
3rd Qu.: 14.00   3rd Qu.:  4.000   3rd Qu.:  4.000
                    Max.   :731.0   Max.   :23.0   Max.   :8474.0   Max.   :701.0000   Max.   :1042.0000   Max.   :650.0000
Max.   :304.00   Max.   :116.000   Max.   :128.000
   num_videos    average_token_length  num_keywords    data_channel_is_lifestyle data_channel_is_entertainment data_channel_
is_bus data_channel_is_socmed data_channel_is_tech data_channel_is_world
 Min.   : 0.00   Min.   :0.000        Min.   : 1.000   Min.   :0.00000          Min.   :0.000                Min.   :0.000
0      Min.   :0.0000         Min.   :0.0000       Min.   :0.0000
 1st Qu.: 0.00   1st Qu.:4.478        1st Qu.: 6.000   1st Qu.:0.00000          1st Qu.:0.000                1st Qu.:0.000
0      1st Qu.:0.0000         1st Qu.:0.0000       1st Qu.:0.0000
 Median : 0.00   Median :4.664        Median : 7.000   Median :0.00000          Median :0.000                Median :0.000
0      Median :0.0000         Median :0.0000       Median :0.0000
 Mean   : 1.25   Mean   :4.548        Mean   : 7.224   Mean   :0.05295          Mean   :0.178                Mean   :0.157
9      Mean   :0.0586         Mean   :0.1853       Mean   :0.2126
 3rd Qu.: 1.00   3rd Qu.:4.855        3rd Qu.: 9.000   3rd Qu.:0.00000          3rd Qu.:0.000                3rd Qu.:0.000
0      3rd Qu.:0.0000         3rd Qu.:0.0000       3rd Qu.:0.0000
 Max.   :91.00   Max.   :8.042        Max.   :10.000   Max.   :1.00000          Max.   :1.000                Max.   :1.000
0      Max.   :1.0000         Max.   :1.0000       Max.   :1.0000
   kw_min_min       kw_max_min       kw_avg_min        kw_min_max       kw_max_max       kw_avg_max       kw_min_avg     kw_
max_avg       kw_avg_avg    self_reference_min_shares
 Min.   : -1.00   Min.   :     0   Min.   :   -1.0   Min.   :     0   Min.   :     0   Min.   :     0   Min.   :  -1   Min.
:     0   Min.   :    0   Min.   :     0
 1st Qu.: -1.00   1st Qu.:   445   1st Qu.:  141.8   1st Qu.:     0   1st Qu.:843300   1st Qu.:172847   1st Qu.:   0   1st Q
u.:  3562   1st Qu.: 2382   1st Qu.:   639
 Median : -1.00   Median :   660   Median :  235.5   Median :  1400   Median :843300   Median :244572   Median :1024   Media
n :  4356   Median : 2870   Median :  1200
 Mean   : 26.11   Mean   :  1154   Mean   :  312.4   Mean   : 13612   Mean   :752324   Mean   :259282   Mean   :1117   Mean
:  5657   Mean   : 3136   Mean   :  3999
 3rd Qu.:  4.00   3rd Qu.:  1000   3rd Qu.:  357.0   3rd Qu.:  7900   3rd Qu.:843300   3rd Qu.:330980   3rd Qu.:2057   3rd Q
u.:  6020   3rd Qu.: 3600   3rd Qu.:  2600
 Max.   :377.00   Max.   :298400   Max.   :42827.9   Max.   :843300   Max.   :843300   Max.   :843300   Max.   :3613   Max.
:298400   Max.   :43568   Max.   :843300
 self_reference_max_shares self_reference_avg_sharess weekday_is_monday weekday_is_tuesday weekday_is_wednesday weekday_is_t
hursday weekday_is_friday weekday_is_saturday weekday_is_sunday
 Min.   :     0            Min.   :     0.0           Min.   :0.000     Min.   :0.0000     Min.   :0.0000       Min.   :0.00
00      Min.   :0.0000    Min.   :0.00000     Min.   :0.00000
 1st Qu.:  1100            1st Qu.:   981.2           1st Qu.:0.000     1st Qu.:0.0000     1st Qu.:0.0000       1st Qu.:0.00
00      1st Qu.:0.0000    1st Qu.:0.00000     1st Qu.:0.00000
 Median :  2800            Median :  2200.0           Median :0.000     Median :0.0000     Median :0.0000       Median :0.00
00      Median :0.0000    Median :0.00000     Median :0.00000
 Mean   : 10329            Mean   :  6401.7           Mean   :0.168     Mean   :0.1864     Mean   :0.1875       Mean   :0.18
33      Mean   :0.1438    Mean   :0.06188     Mean   :0.06904
 3rd Qu.:  8000            3rd Qu.:  5200.0           3rd Qu.:0.000     3rd Qu.:0.0000     3rd Qu.:0.0000       3rd Qu.:0.00
00      3rd Qu.:0.0000    3rd Qu.:0.00000     3rd Qu.:0.00000
 Max.   :843300            Max.   :843300.0           Max.   :1.000     Max.   :1.0000     Max.   :1.0000       Max.   :1.00
00      Max.   :1.0000    Max.   :1.00000     Max.   :1.00000
   is_weekend         LDA_00            LDA_01            LDA_02            LDA_03            LDA_04         global_subjectiv
ity global_sentiment_polarity global_rate_positive_words
 Min.   :0.0000   Min.   :0.00000   Min.   :0.00000   Min.   :0.00000   Min.   :0.00000   Min.   :0.00000   Min.   :0.0000
Min.   :-0.39375          Min.   :0.00000
 1st Qu.:0.0000   1st Qu.:0.02505   1st Qu.:0.02501   1st Qu.:0.02857   1st Qu.:0.02857   1st Qu.:0.02857   1st Qu.:0.3962
1st Qu.: 0.05776          1st Qu.:0.02838
 Median :0.0000   Median :0.03339   Median :0.03334   Median :0.04000   Median :0.04000   Median :0.04073   Median :0.4535
Median : 0.11912          Median :0.03902
 Mean   :0.1309   Mean   :0.18460   Mean   :0.14126   Mean   :0.21632   Mean   :0.22377   Mean   :0.23403   Mean   :0.4434
Mean   : 0.11931          Mean   :0.03962
 3rd Qu.:0.0000   3rd Qu.:0.24096   3rd Qu.:0.15083   3rd Qu.:0.33422   3rd Qu.:0.37576   3rd Qu.:0.39999   3rd Qu.:0.5083
3rd Qu.: 0.17783          3rd Qu.:0.05028
 Max.   :1.0000   Max.   :0.92699   Max.   :0.92595   Max.   :0.92000   Max.   :0.92653   Max.   :0.92719   Max.   :1.0000
Max.   : 0.72784          Max.   :0.15549
 global_rate_negative_words rate_positive_words rate_negative_words avg_positive_polarity min_positive_polarity max_positive
_polarity avg_negative_polarity min_negative_polarity
 Min.   :0.000000           Min.   :0.0000      Min.   :0.0000      Min.   :0.0000        Min.   :0.00000       Min.   :0.00
00        Min.   :-1.0000       Min.   :-1.0000
 1st Qu.:0.009615           1st Qu.:0.6000      1st Qu.:0.1852      1st Qu.:0.3062        1st Qu.:0.05000       1st Qu.:0.60
00        1st Qu.:-0.3284       1st Qu.:-0.7000
 Median :0.015337           Median :0.7105      Median :0.2800      Median :0.3588        Median :0.10000       Median :0.80
00        Median :-0.2533       Median :-0.5000
 Mean   :0.016612           Mean   :0.6822      Mean   :0.2879      Mean   :0.3538        Mean   :0.09545       Mean   :0.75
67        Mean   :-0.2595       Mean   :-0.5219
 3rd Qu.:0.021739           3rd Qu.:0.8000      3rd Qu.:0.3846      3rd Qu.:0.4114        3rd Qu.:0.10000       3rd Qu.:1.00
00        3rd Qu.:-0.1869       3rd Qu.:-0.3000
 Max.   :0.184932           Max.   :1.0000      Max.   :1.0000      Max.   :1.0000        Max.   :1.00000       Max.   :1.00
```

```
00        Max.   : 0.0000       Max.   : 0.0000
 max_negative_polarity title_subjectivity title_sentiment_polarity abs_title_subjectivity abs_title_sentiment_polarity     s
hares
 Min.   :-1.0000       Min.   :0.0000     Min.   :-1.00000         Min.   :0.0000         Min.   :0.0000               Min.
:     1
 1st Qu.:-0.1250       1st Qu.:0.0000     1st Qu.: 0.00000         1st Qu.:0.1667         1st Qu.:0.0000               1st Q
u.:   946
 Median :-0.1000       Median :0.1500     Median : 0.00000         Median :0.5000         Median :0.0000               Media
n :  1400
 Mean   :-0.1075       Mean   :0.2824     Mean   : 0.07143         Mean   :0.3418         Mean   :0.1561               Mean
:  3395
 3rd Qu.:-0.0500       3rd Qu.:0.5000     3rd Qu.: 0.15000         3rd Qu.:0.5000         3rd Qu.:0.2500               3rd Q
u.:  2800
 Max.   : 0.0000       Max.   :1.0000     Max.   : 1.00000         Max.   :0.5000         Max.   :1.0000               Max.
:843300
```

The dataset has 39,644 samples and 61 variables.

Missing Data

Hide

```
sum(is.na(df))
```

```
[1] 0
```

None of the variables is missing any data so there is no need for imputation.

Define Target and Predictors

Hide

```
df <- df[, names(df) != "url"] # drop the url column, which functions as a sample ID
y <- df$shares # shares is the target variable
X <- df[, names(df) != "shares"]
```

Target Distribution

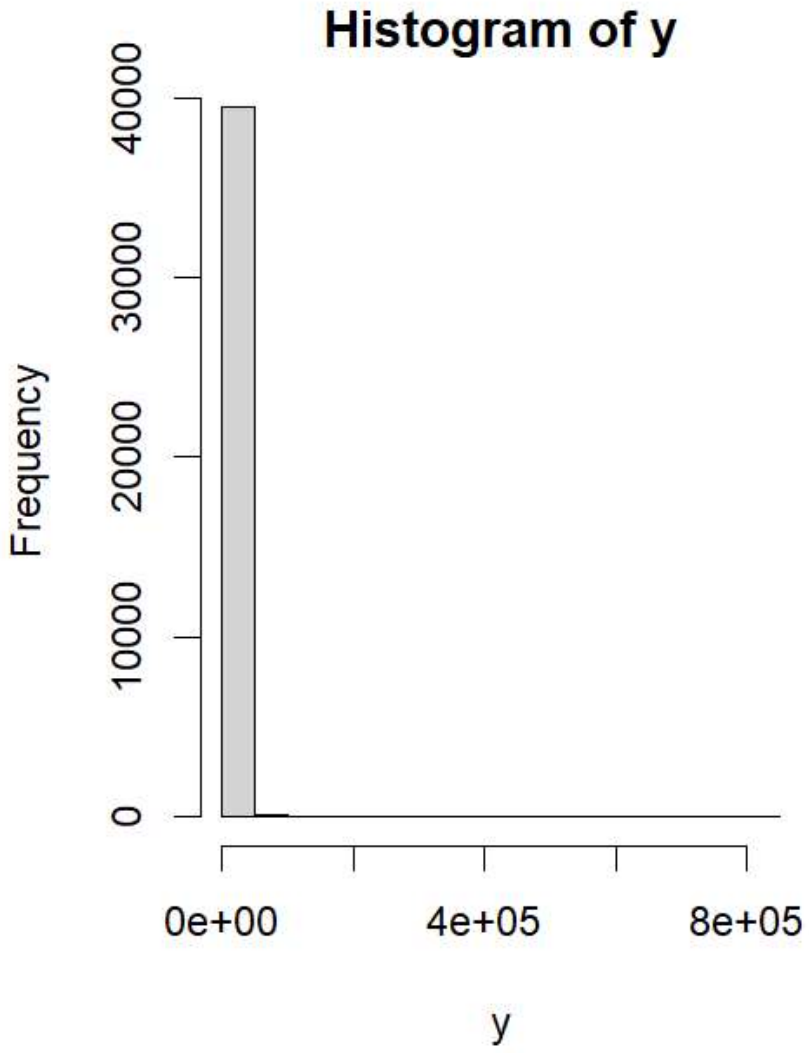
Hide

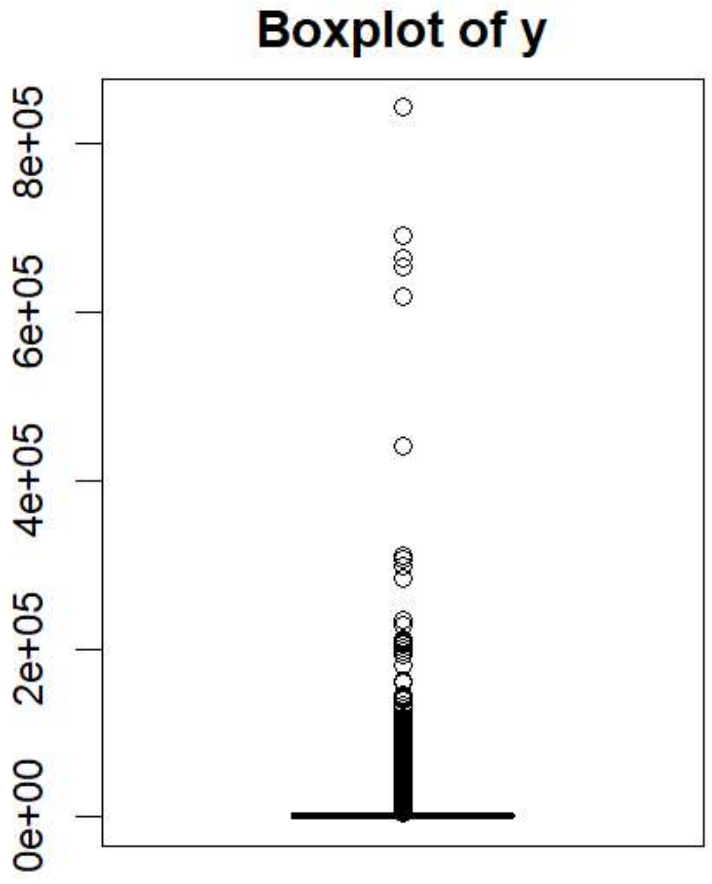
```
summary(y)
```

```
   Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
      1     946    1400    3395    2800  843300
```

Hide

```
par(mfrow = c(1, 2))
hist(y)
boxplot(y, main = "Boxplot of y")
```





The target distribution is highly right-skewed. Let’s try log transforming it.

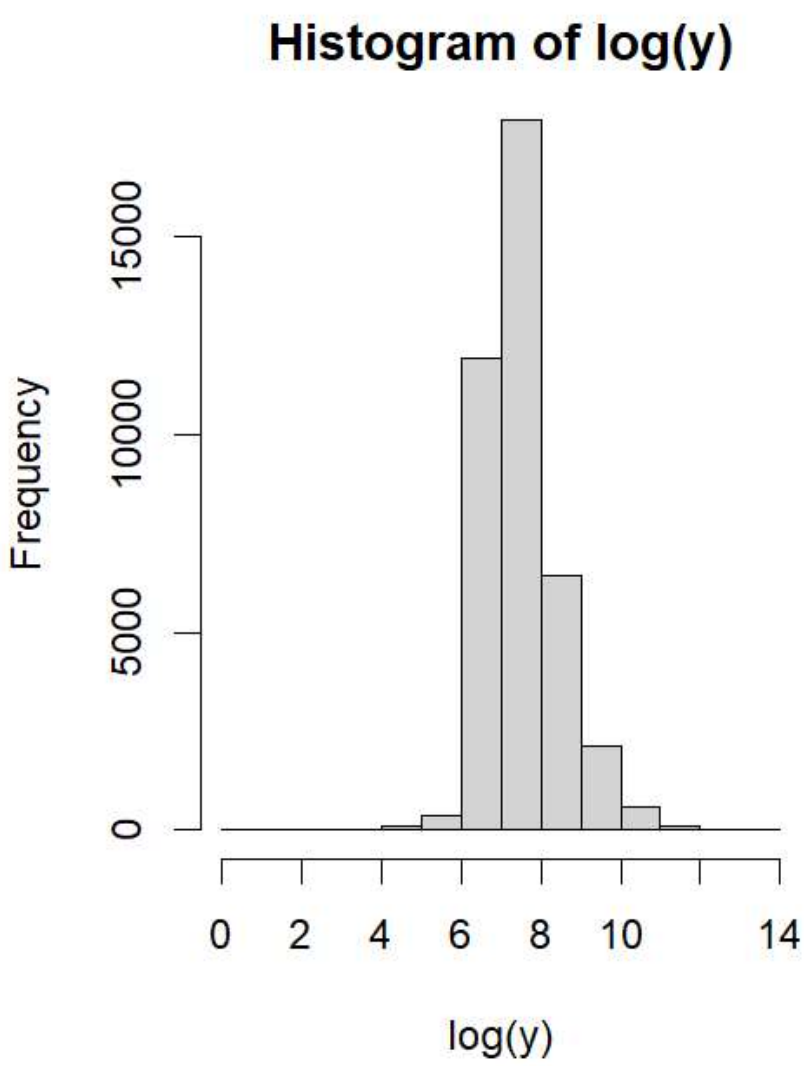
Hide

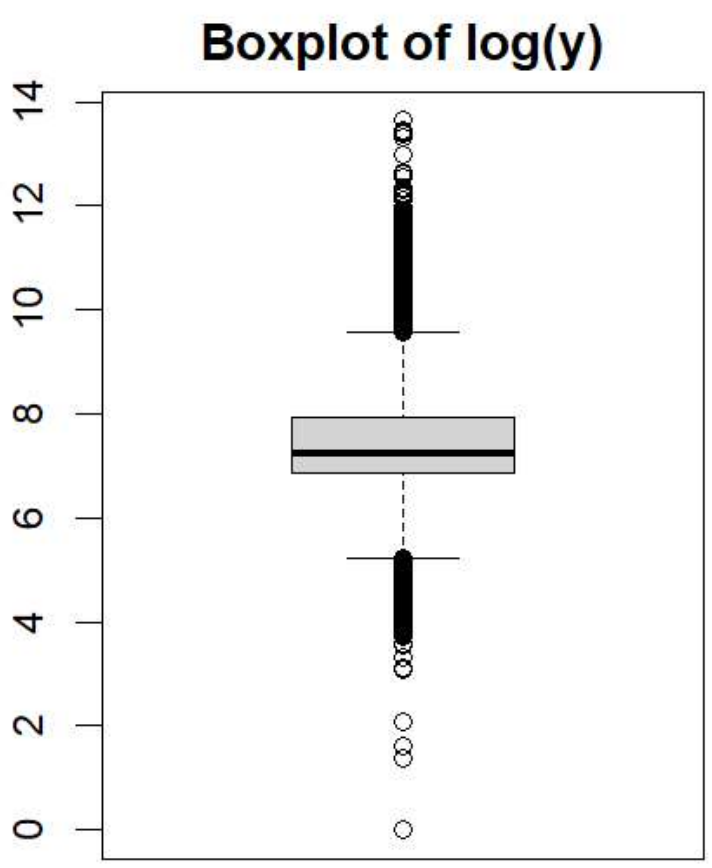
```
summary(log(y))
```

```
   Min. 1st Qu.  Median    Mean 3rd Qu.    Max. 
  0.000   6.852   7.244   7.475   7.937  13.645 
```

Hide

```
par(mfrow = c(1, 2))
hist(log(y))
boxplot(log(y), main = "Boxplot of log(y)")
```





The log of the target is much less skewed. Let’s use the log-transformed version.

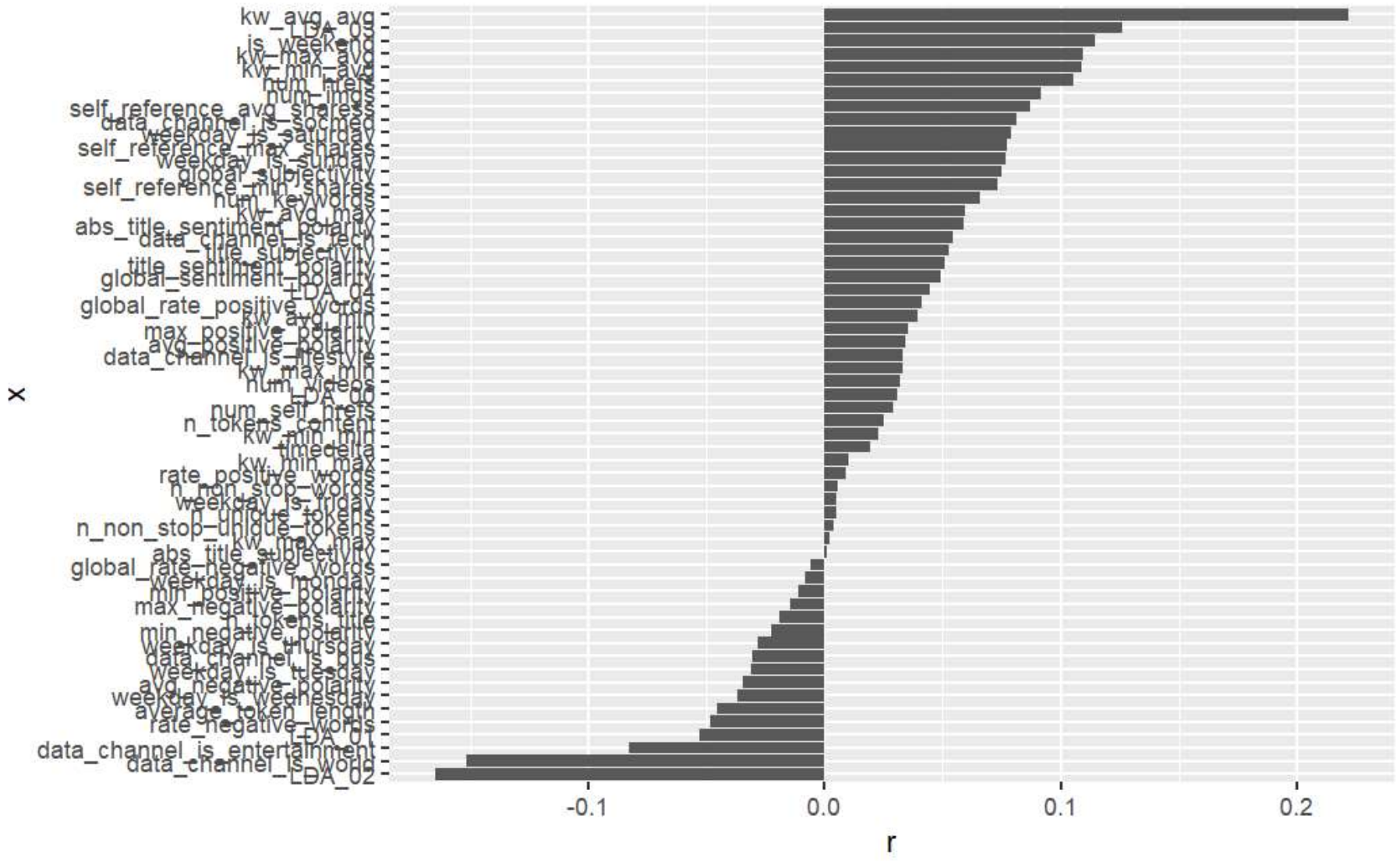
Hide

```
y <- log(y)
```

Target-Predictor Correlations

Hide

```
library(tidyr)
library(dplyr)
library(ggplot2)
x <- names(X)
correlations <- data.frame(x)
correlations$r <- apply(correlations, 1, function(row) cor(X[, row["x"]], y)) # correlation between each predictor and the t
arget
correlations <- correlations %>%
  dplyr::arrange(r) %>%
  dplyr::mutate(x = forcats::fct_inorder(x))
ggplot(correlations) +
  geom_col(aes(x = x, y = r)) +
  coord_flip()
```



Hide

```
correlations
```

x	r
<fctr>	<dbl>
LDA_02	-0.1650336120
data_channel_is_world	-0.1516506202
data_channel_is_entertainment	-0.0825036542
LDA_01	-0.0529932702
rate_negative_words	-0.0481707553
average_token_length	-0.0452834316
weekday_is_wednesday	-0.0365902248
avg_negative_polarity	-0.0343099860
weekday_is_tuesday	-0.0310734298
data_channel_is_bus	-0.0305990105

1-10 of 59 rows Previous **1** 2 3 4 5 6 Next

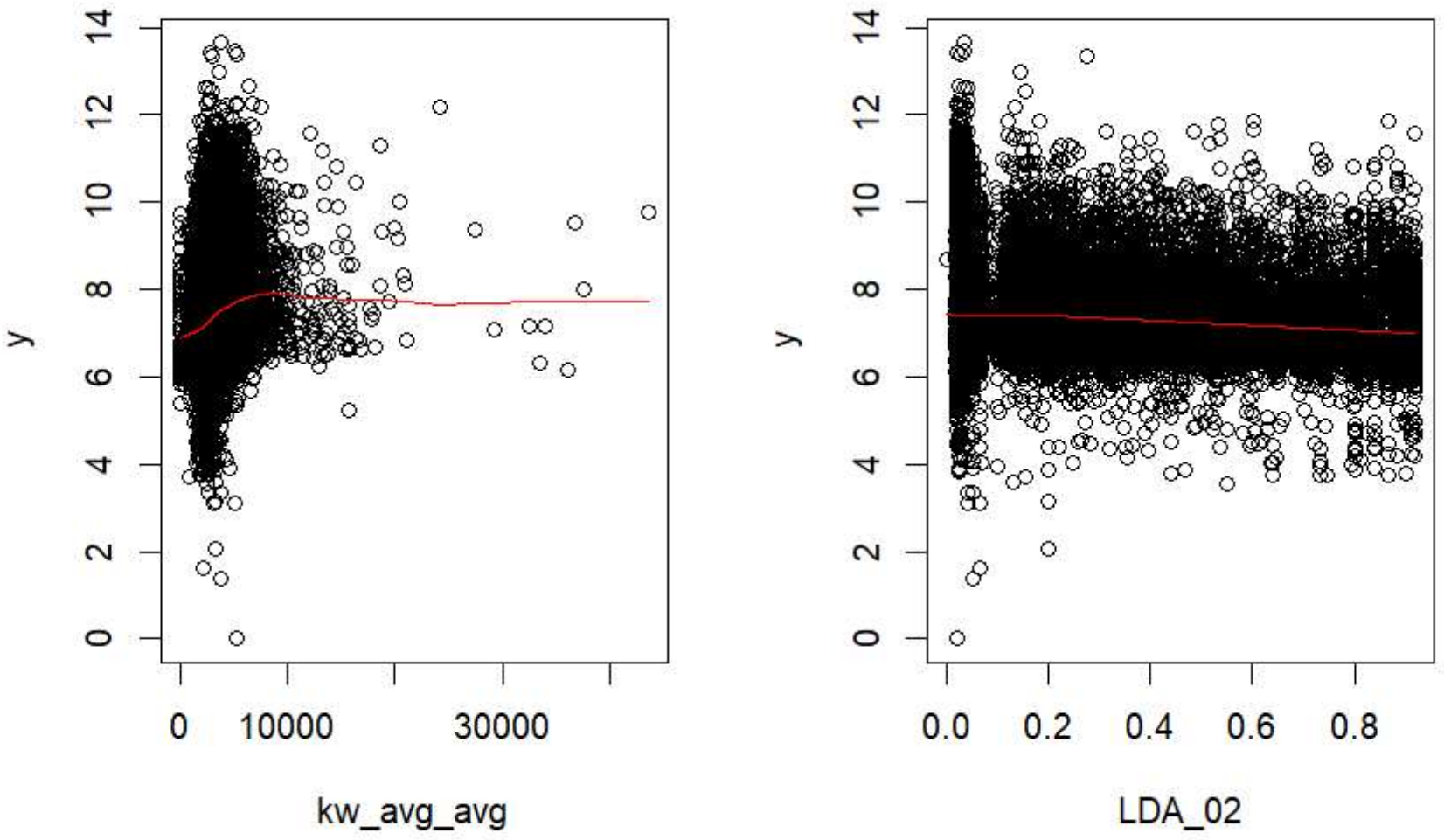
None of the target-predictor correlations is very strong. The strongest positive correlation is with kw_avg_avg, while the strongest negative correlation is with LDA_02.

Hide

```
par(mfrow = c(1, 2))

plot(X[, "kw_avg_avg"], y, xlab = "kw_avg_avg")
lines(lowess(X[, "kw_avg_avg"], y), col = "red")
```

Hide

```
plot(X[, "LDA_02"], y, xlab = "LDA_02")
lines(lowess(X[, "LDA_02"], y), col = "red")
```



Predictor Distributions

Near-Zero Variance

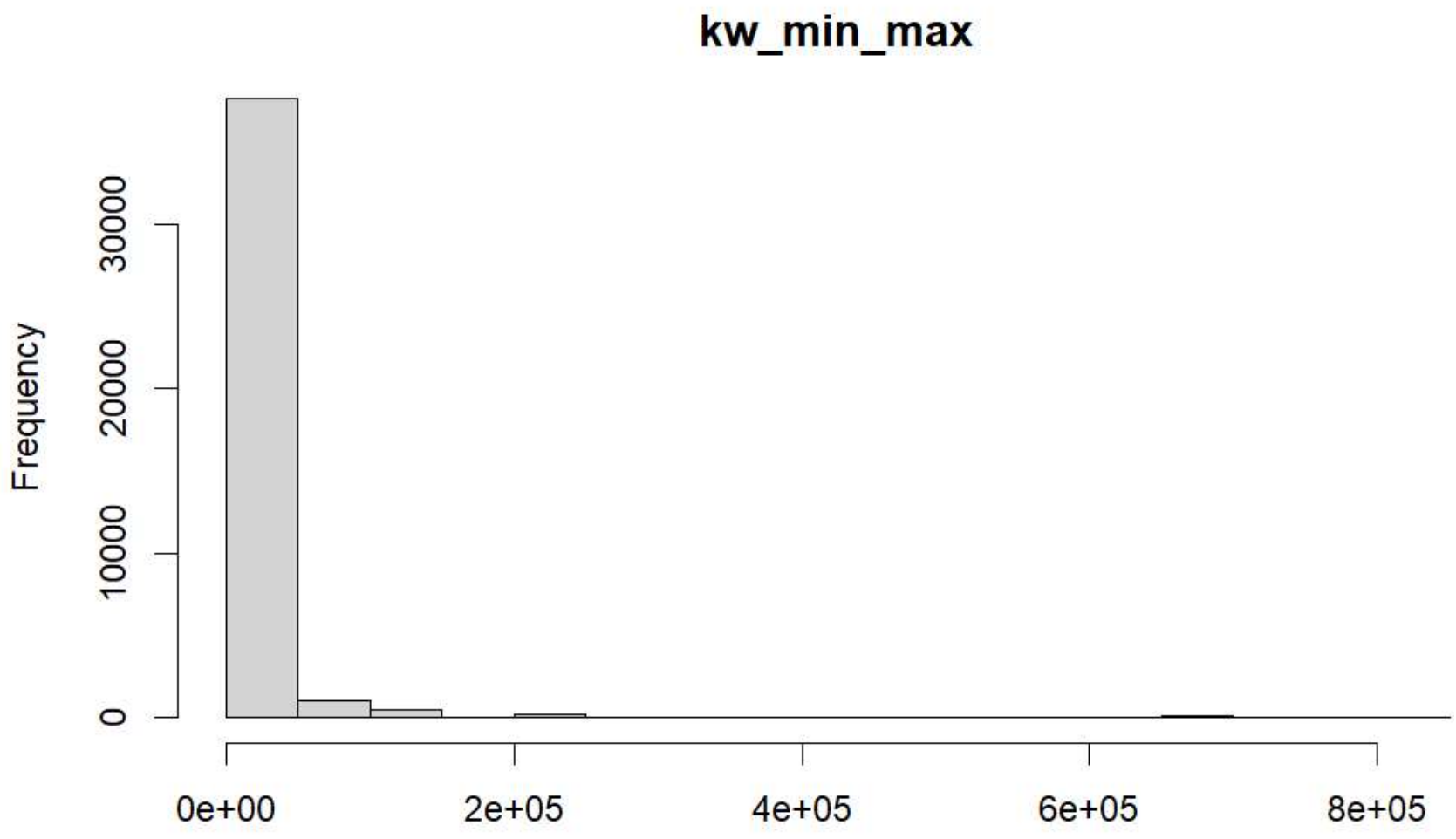
Hide

```
library(caret)
```

```
Loading required package: ggplot2
Loading required package: lattice
```

Hide

```
degen.cols <- nearZeroVar(X)
for (i in degen.cols) {
  col.name <- names(X)[i]
  hist(X[, col.name], main = col.name, xlab = col.name)
}
```



kw_min_max

kw_min_max has near-zero variance so let's remove it.

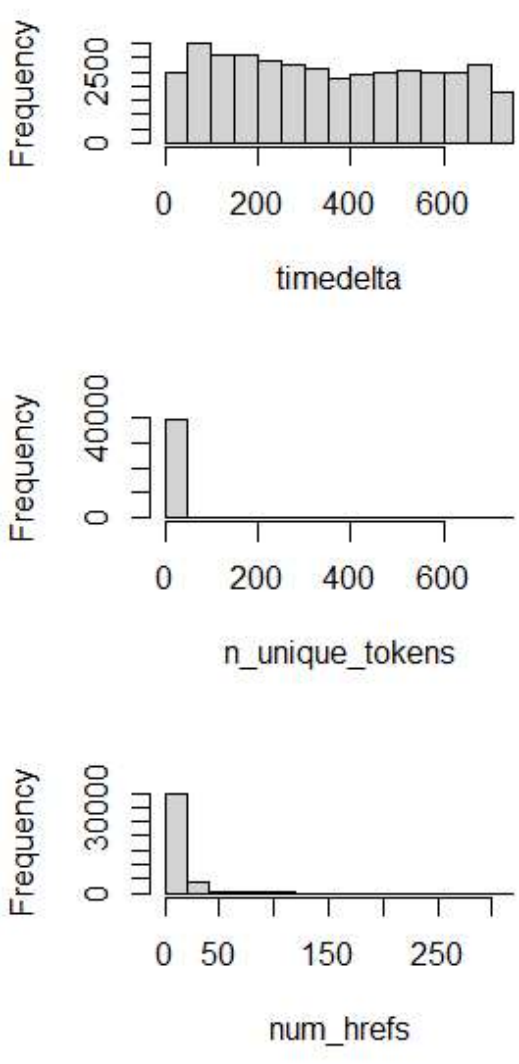
Hide

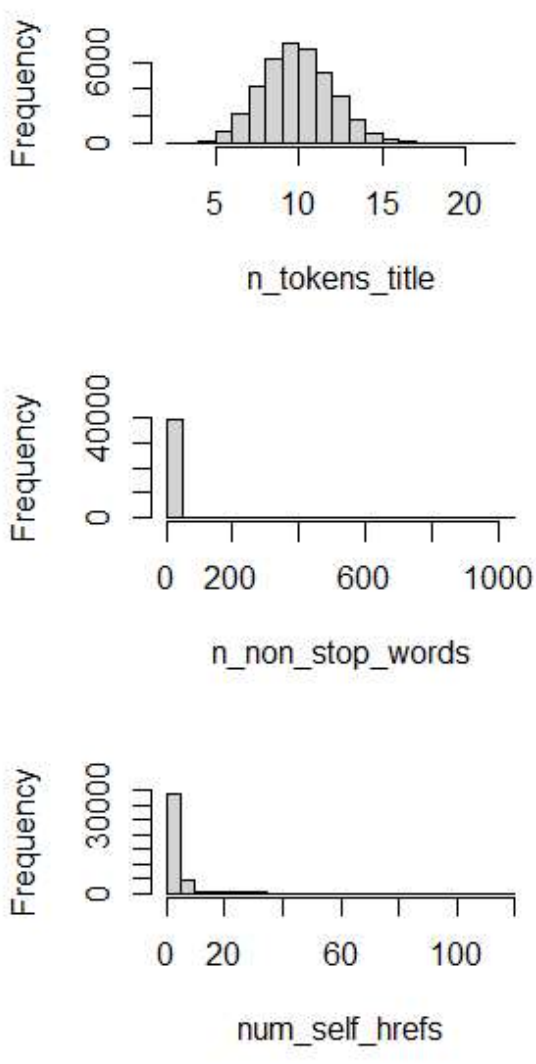
```
X <- X[, -degen.cols]
```

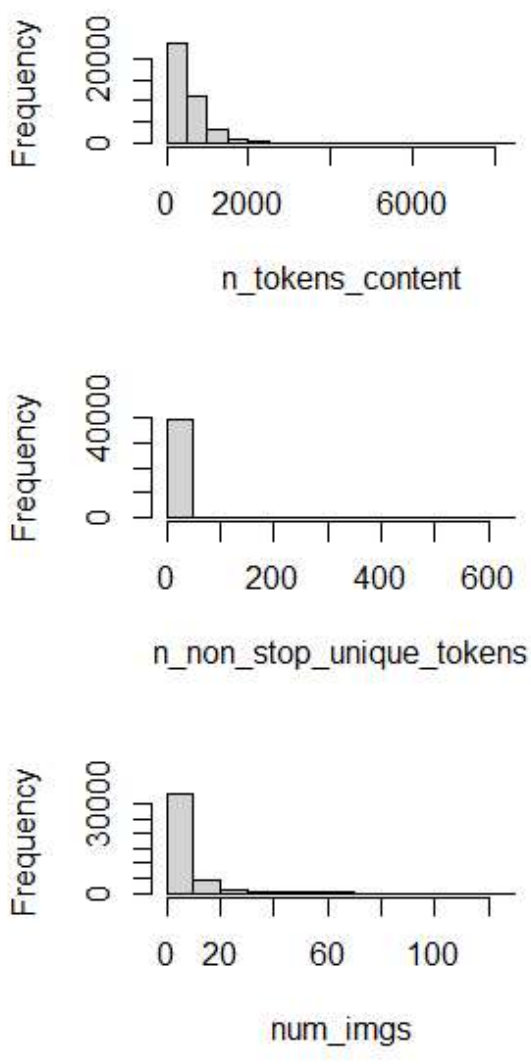
Skew

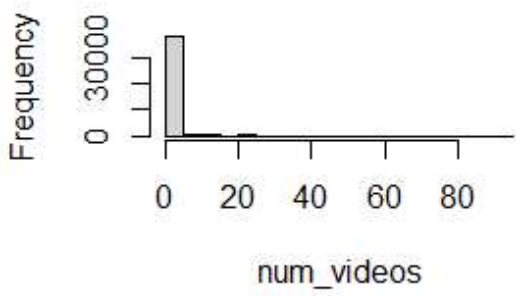
Hide

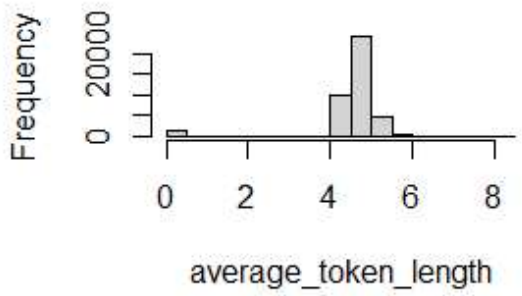
```
par(mfrow = c(3, 3))
for (i in 1:ncol(X)) {
  hist(
    X[, i],
    main = NULL,
    xlab = colnames(X)[i]
  )
}
```

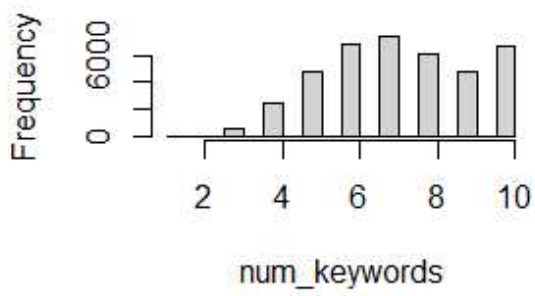


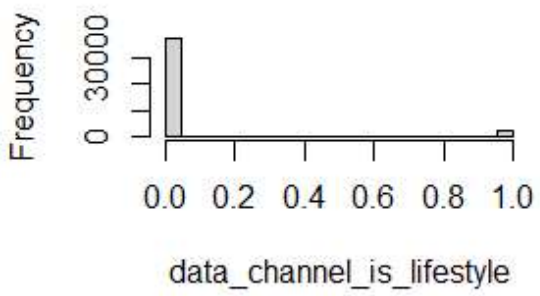


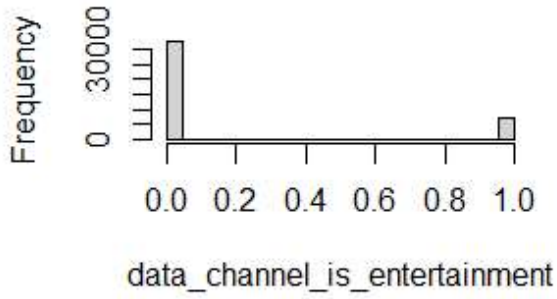


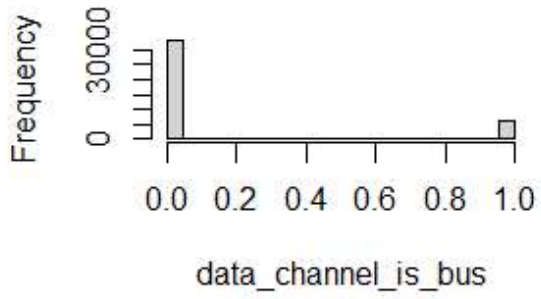

Frequency
0 30000
0 20 40 60 80
num_videos

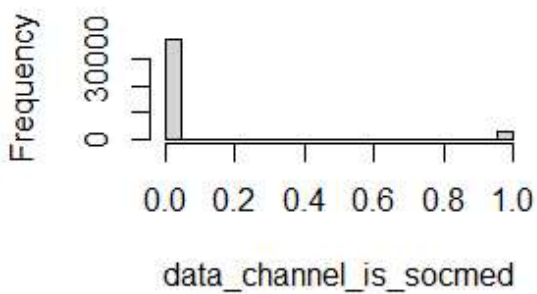

Frequency
0 20000
0 2 4 6 8
average_token_length

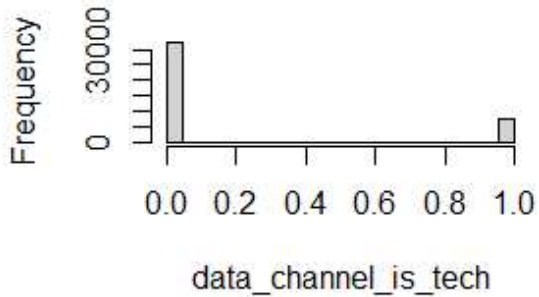

Frequency
0 6000
2 4 6 8 10
num_keywords

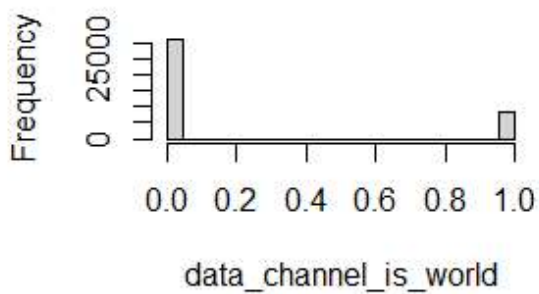

Frequency
0 30000
0.0 0.2 0.4 0.6 0.8 1.0
data_channel_is_lifestyle

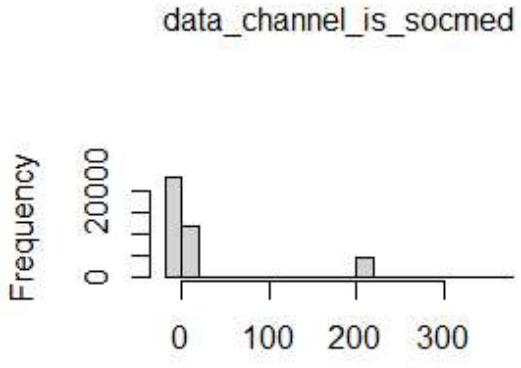

Frequency
0 30000
0.0 0.2 0.4 0.6 0.8 1.0
data_channel_is_entertainment

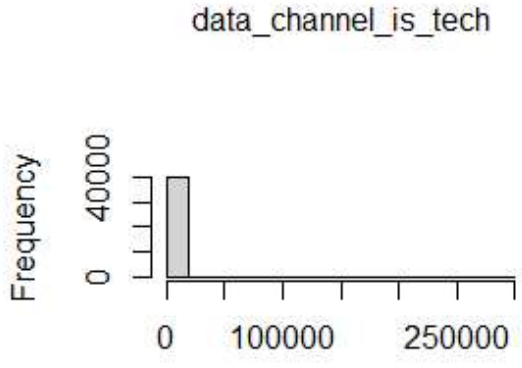

Frequency
0 30000
0.0 0.2 0.4 0.6 0.8 1.0
data_channel_is_bus

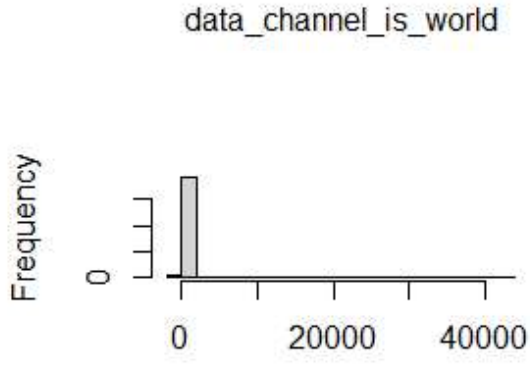

Frequency
0 30000
0.0 0.2 0.4 0.6 0.8 1.0
data_channel_is_socmed

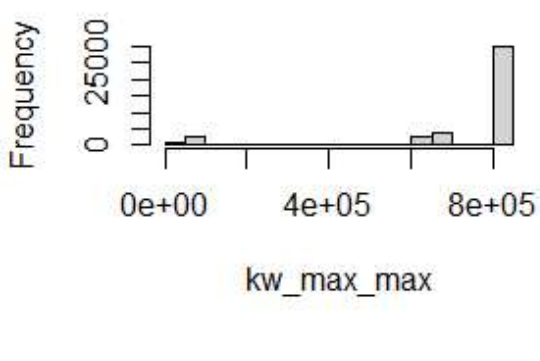

Frequency
0 30000
0.0 0.2 0.4 0.6 0.8 1.0
data_channel_is_tech

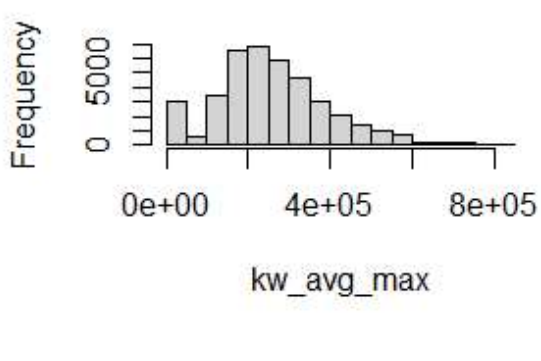

Frequency
0 25000
0.0 0.2 0.4 0.6 0.8 1.0
data_channel_is_world

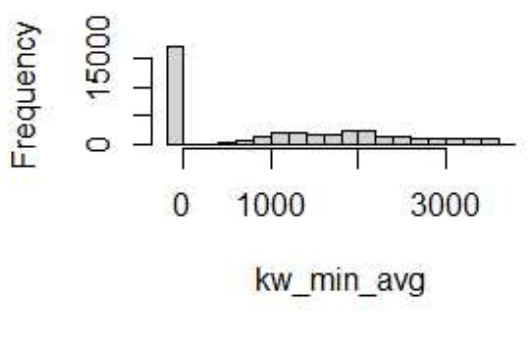

Frequency
0 20000
0 100 200 300
kw_min_min

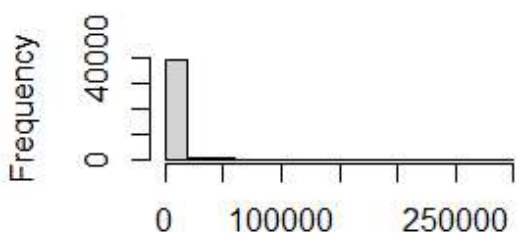

Frequency
0 40000
0 100000 250000
kw_max_min

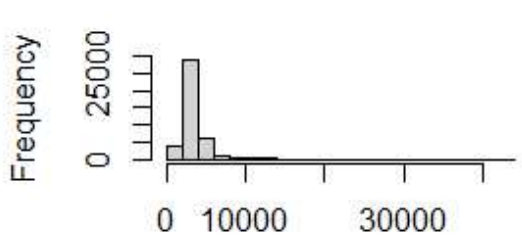

Frequency
0
0 20000 40000
kw_avg_min

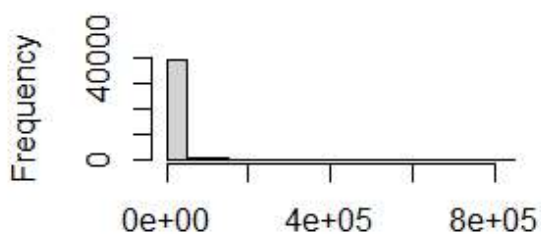

Frequency
0 25000
0e+00 4e+05 8e+05
kw_max_max

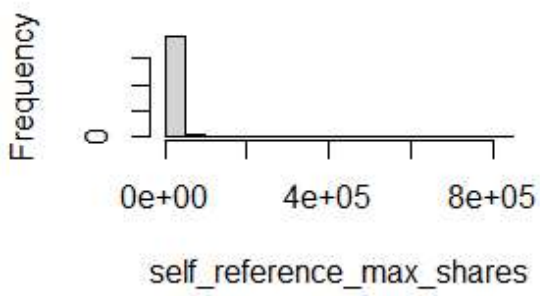

Frequency
0 5000
0e+00 4e+05 8e+05
kw_avg_max

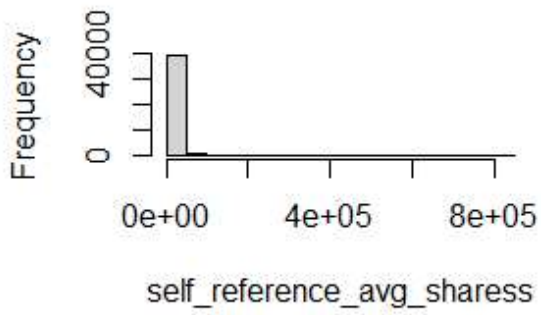

Frequency
0 15000
0 1000 3000
kw_min_avg

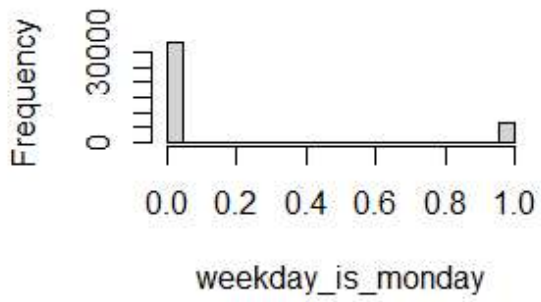

Frequency
0 40000
0 100000 250000
kw_max_avg

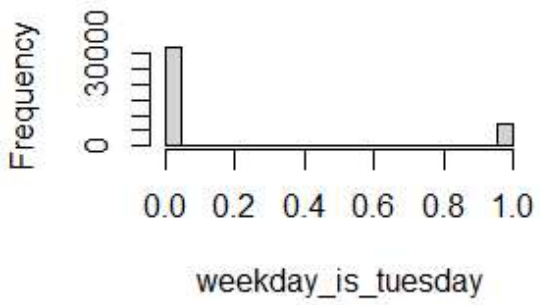

Frequency
0 25000
0 10000 30000
kw_avg_avg

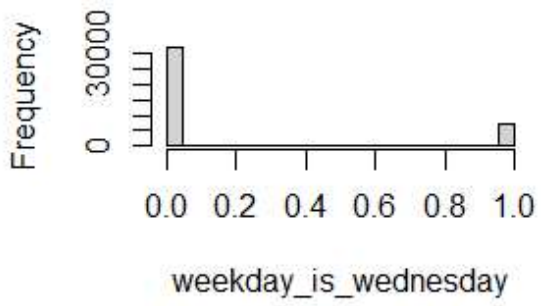

Frequency
0 40000
0e+00 4e+05 8e+05
self_reference_min_shares

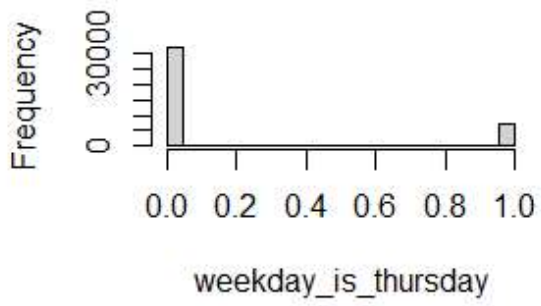

Frequency
0
0e+00
4e+05
8e+05
self_reference_max_shares

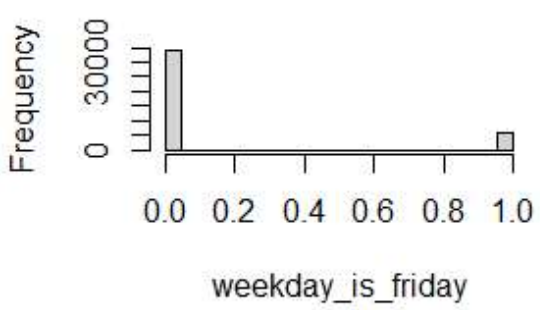

Frequency
0
40000
0e+00
4e+05
8e+05
self_reference_avg_sharess

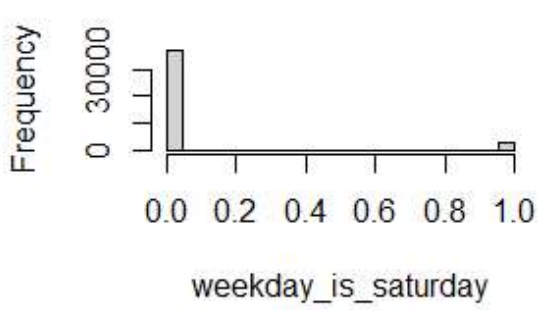

Frequency
0
30000
0.0 0.2 0.4 0.6 0.8 1.0
weekday_is_monday

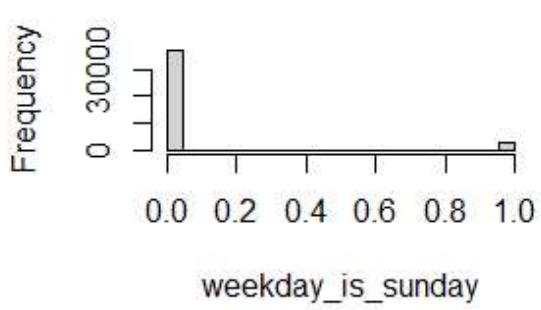

Frequency
0
30000
0.0 0.2 0.4 0.6 0.8 1.0
weekday_is_tuesday

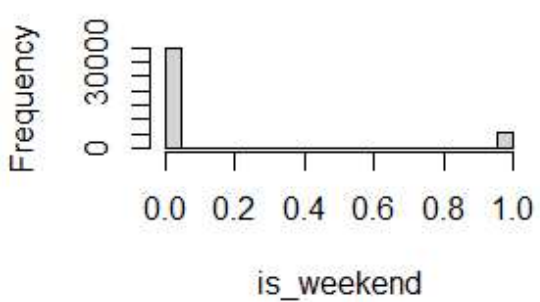

Frequency
0
30000
0.0 0.2 0.4 0.6 0.8 1.0
weekday_is_wednesday

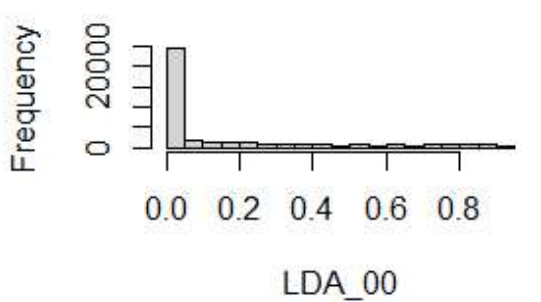

Frequency
0
30000
0.0 0.2 0.4 0.6 0.8 1.0
weekday_is_thursday

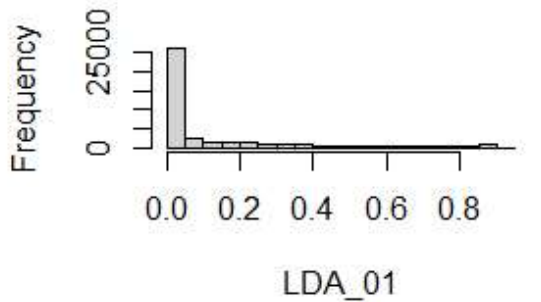

Frequency
0
30000
0.0 0.2 0.4 0.6 0.8 1.0
weekday_is_friday

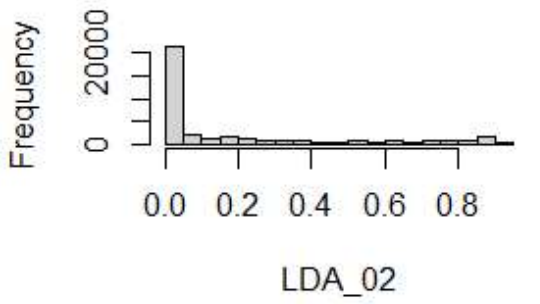

Frequency
0
30000
0.0 0.2 0.4 0.6 0.8 1.0
weekday_is_saturday

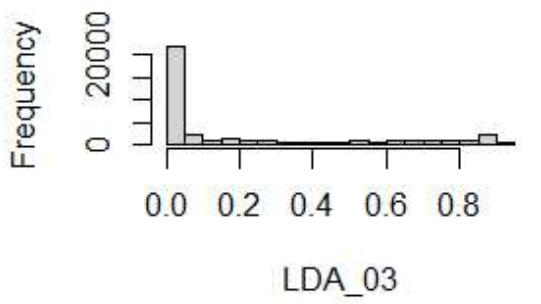

Frequency
0
30000
0.0 0.2 0.4 0.6 0.8 1.0
weekday_is_sunday

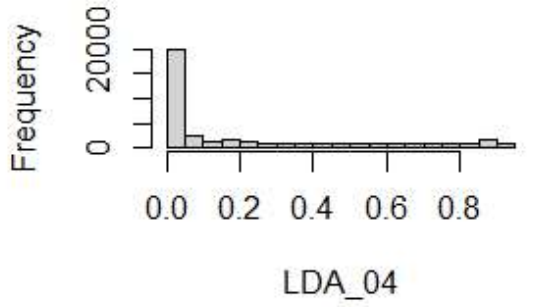

Frequency
0
30000
0.0 0.2 0.4 0.6 0.8 1.0
is_weekend

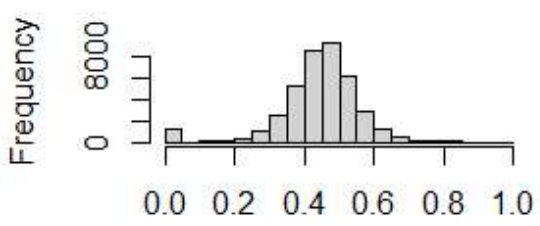

Frequency
0
20000
0.0 0.2 0.4 0.6 0.8
LDA_00

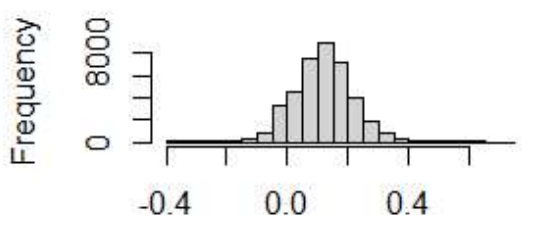

Frequency
0
25000
0.0 0.2 0.4 0.6 0.8
LDA_01

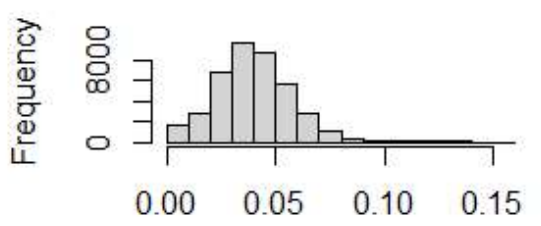

Frequency
0
20000
0.0 0.2 0.4 0.6 0.8
LDA_02

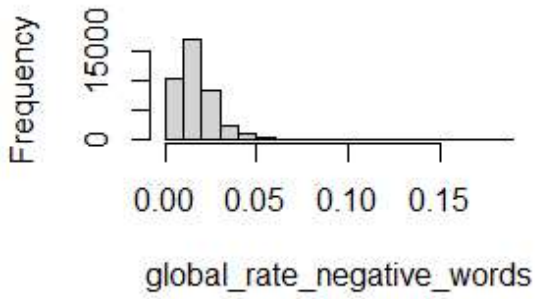

Frequency
0
20000
0.0 0.2 0.4 0.6 0.8
LDA_03

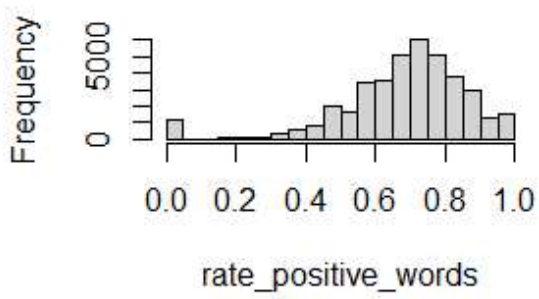

Frequency
0
20000
0.0 0.2 0.4 0.6 0.8
LDA_04

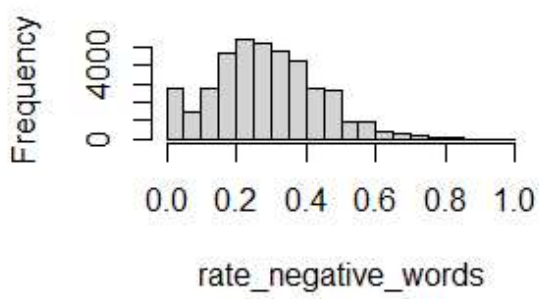

Frequency
0
8000
0.0 0.2 0.4 0.6 0.8 1.0
global_subjectivity

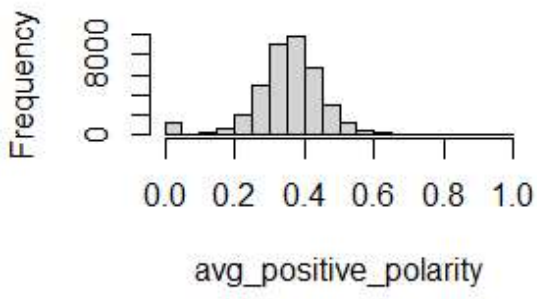

Frequency
0
8000
-0.4 0.0 0.4
global_sentiment_polarity

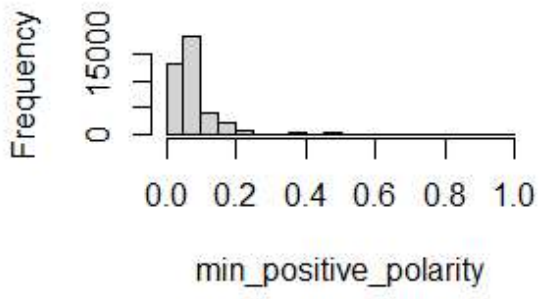

Frequency
0
8000
0.00 0.05 0.10 0.15
global_rate_positive_words

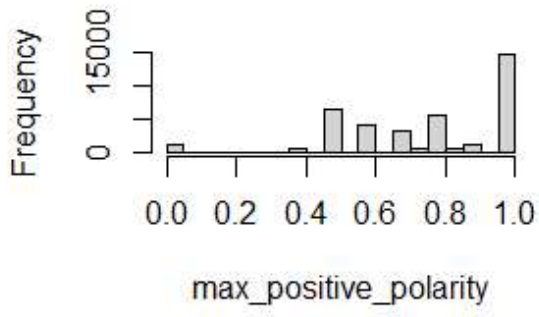


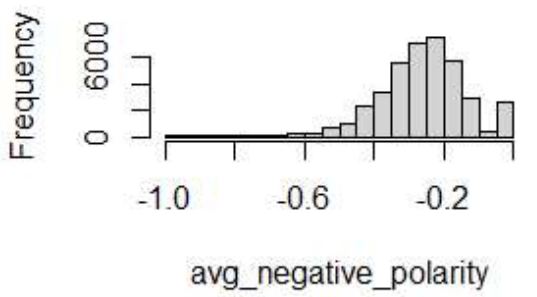


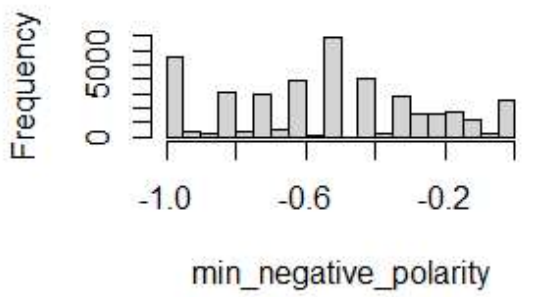


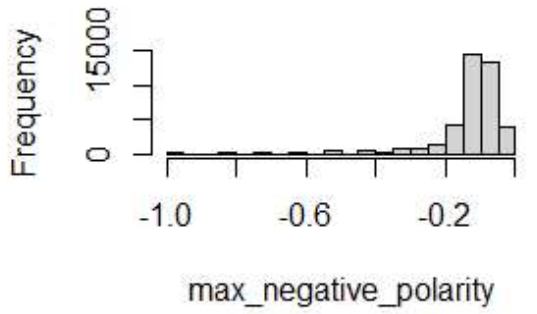


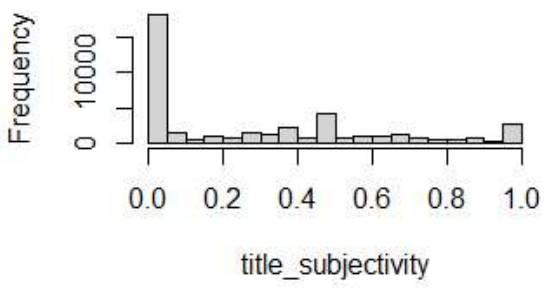


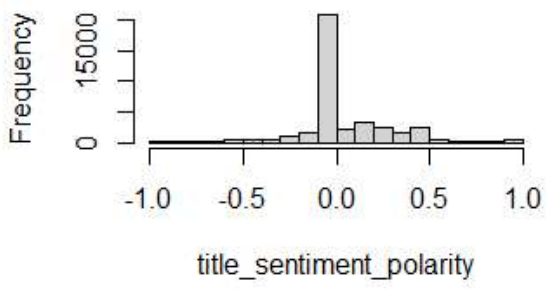


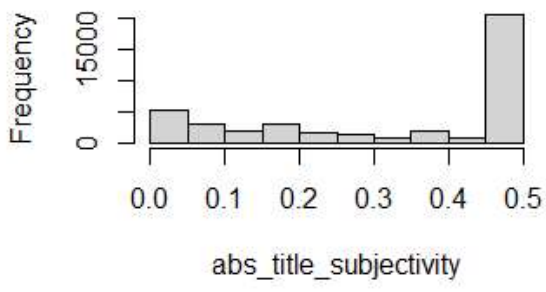


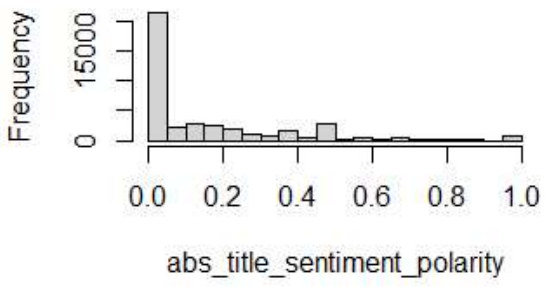












The predictors have widely varying ranges and many are quite skewed. We'll need to center and scale them before modeling.

Correlations

Binary Predictor Correlations

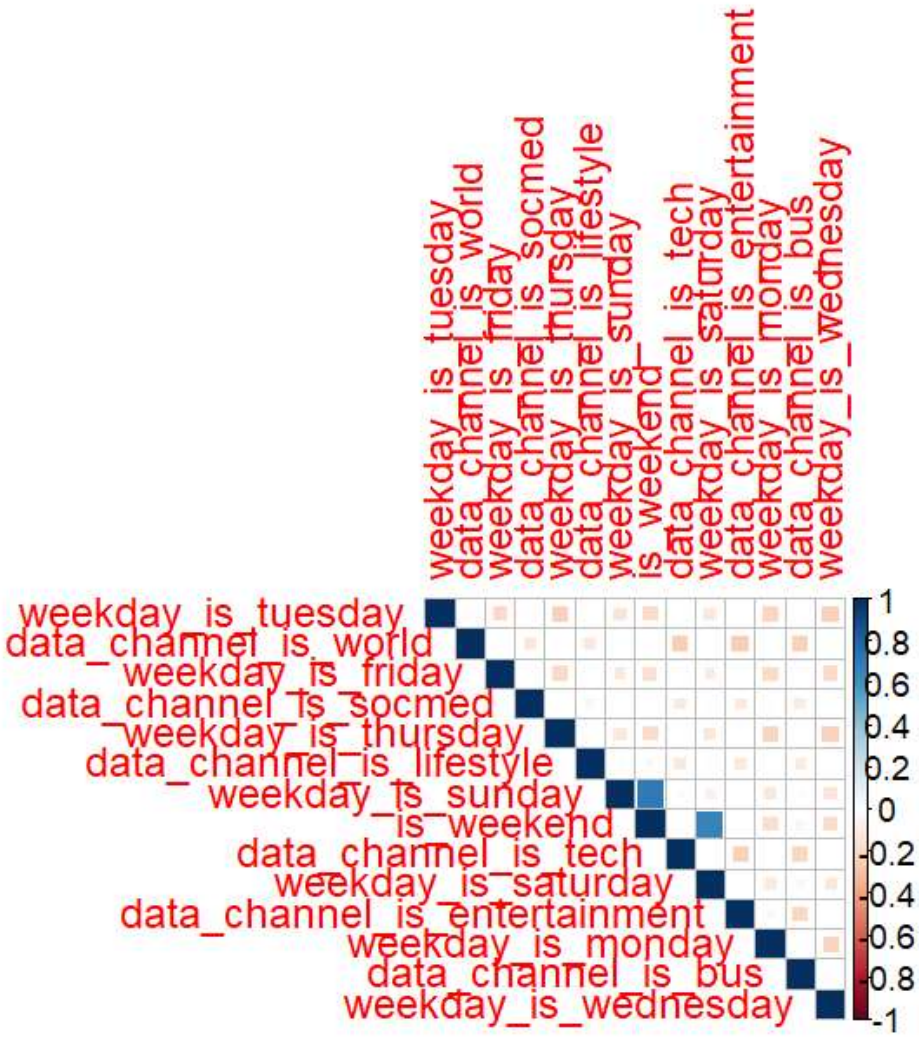
Hide

```
library(corrplot)
```

```
corrplot 0.92 loaded
```

Hide

```
X.bi <- Filter(function(x) all(x %in% c(0, 1)), X)
X.non.bi <- X[, !names(X) %in% names(X.bi)]
cor.bi <- cor(X.bi)
corrplot(
  cor.bi,
  method = "square",
  type = "upper",
  order = "hclust"
)
```



The only strong correlations among the binary predictors are between weekday_is_sunday and is_weekend and between weekday_is_saturday and is_weekend, which makes sense.

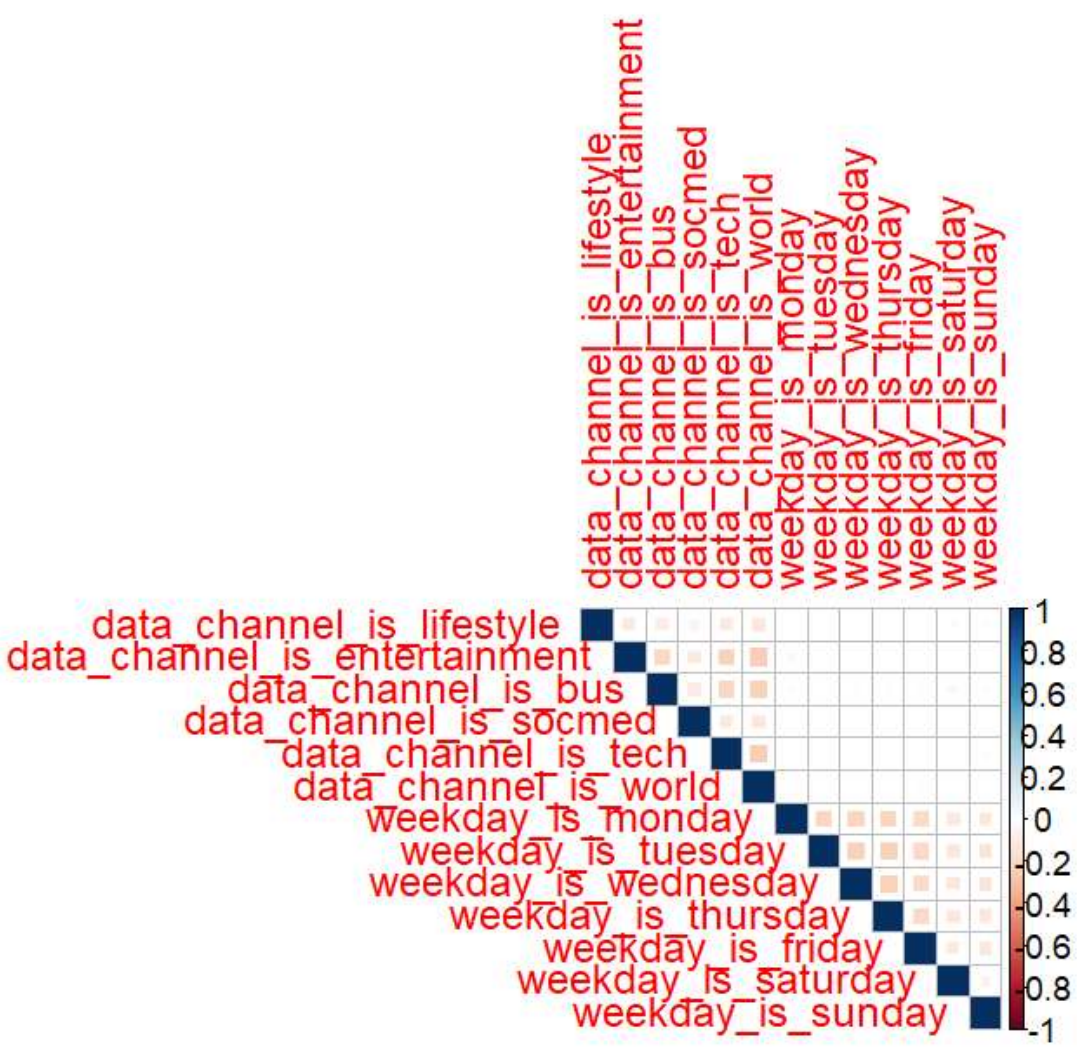
Hide

```
high.cor.bi <- findCorrelation(cor.bi, cutoff = .7)
names(X.bi)[high.cor.bi]
```

```
[1] "is_weekend"
```

Hide

```
X.bi <- X.bi[, -high.cor.bi] # remove is_weekend
cor.bi.filtered <- cor(X.bi)
corrplot(
  cor.bi.filtered,
  method = "square",
  type = "upper"
)
```



Remove weekday_is_sunday to avoid the dummy variable trap. Let's also check the data channel binary predictors for the dummy variable trap.

Hide

```
X.bi <- X.bi[, names(X.bi) != "weekday_is_sunday"]
channels <- c(
  "data_channel_is_world",
  "data_channel_is_socmed",
  "data_channel_is_tech",
  "data_channel_is_bus",
  "data_channel_is_entertainment",
  "data_channel_is_lifestyle"
)
summary(apply(X[, channels], 1, sum)) # check if they always sum to 1 for every sample
```

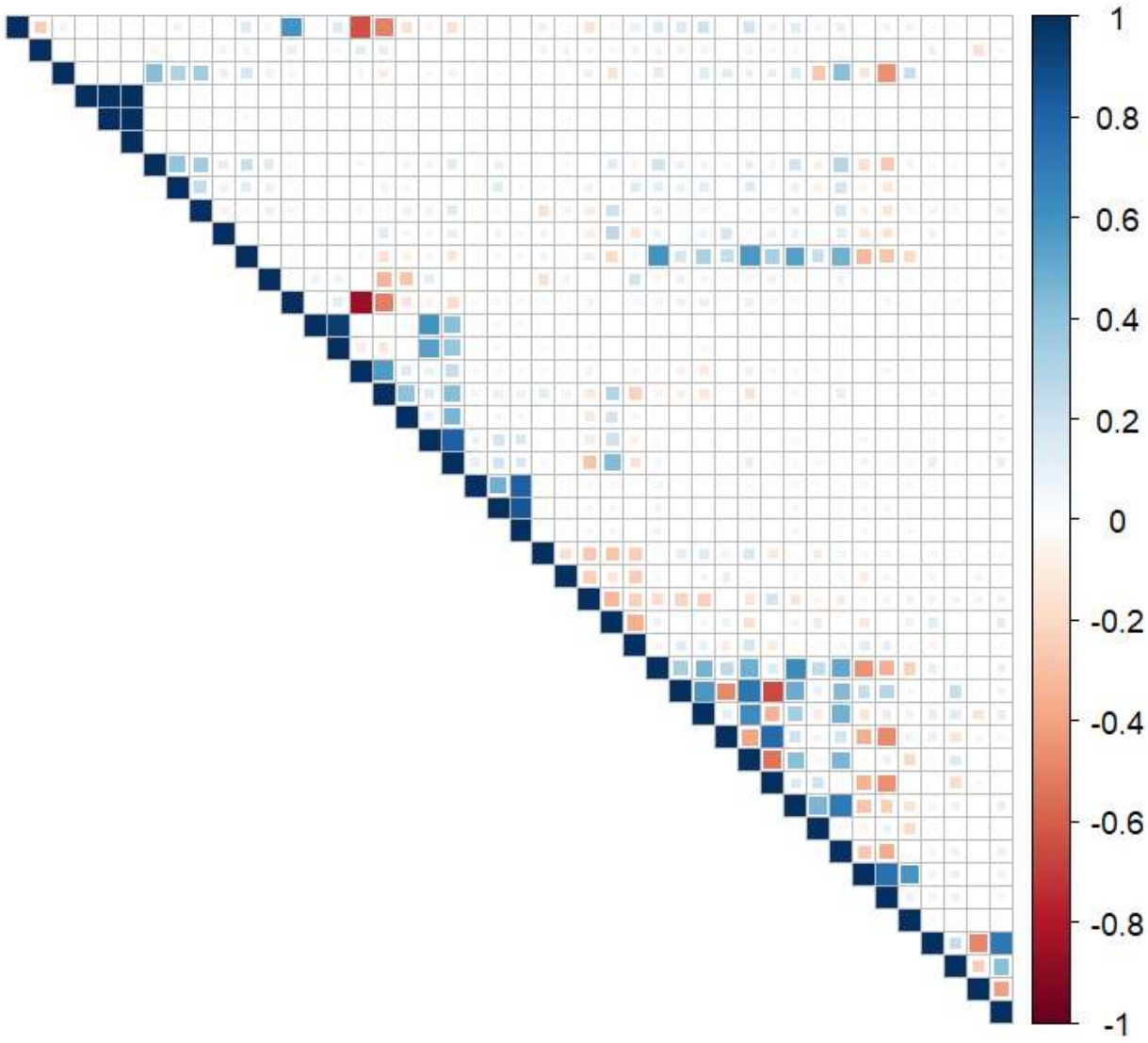
```
   Min. 1st Qu.  Median    Mean 3rd Qu.    Max. 
 0.0000  1.0000  1.0000  0.8453  1.0000  1.0000 
```

The channel predictors do not always sum to 1, so they do not fall into the dummy variable trap.

Non-Binary Predictor Correlations

Hide

```
cor.non.bi <- cor(X.non.bi)
corrplot(
  cor.non.bi,
  method = "square",
  type = "upper",
  tl.pos = "n"
)
```



We can see some strong positive and negative correlations between the non-binary predictors.

Hide

```
high.cor.non.bi <- findCorrelation(cor.non.bi, cutoff = .7)
length(high.cor.non.bi)
```

```
[1] 12
```

Hide

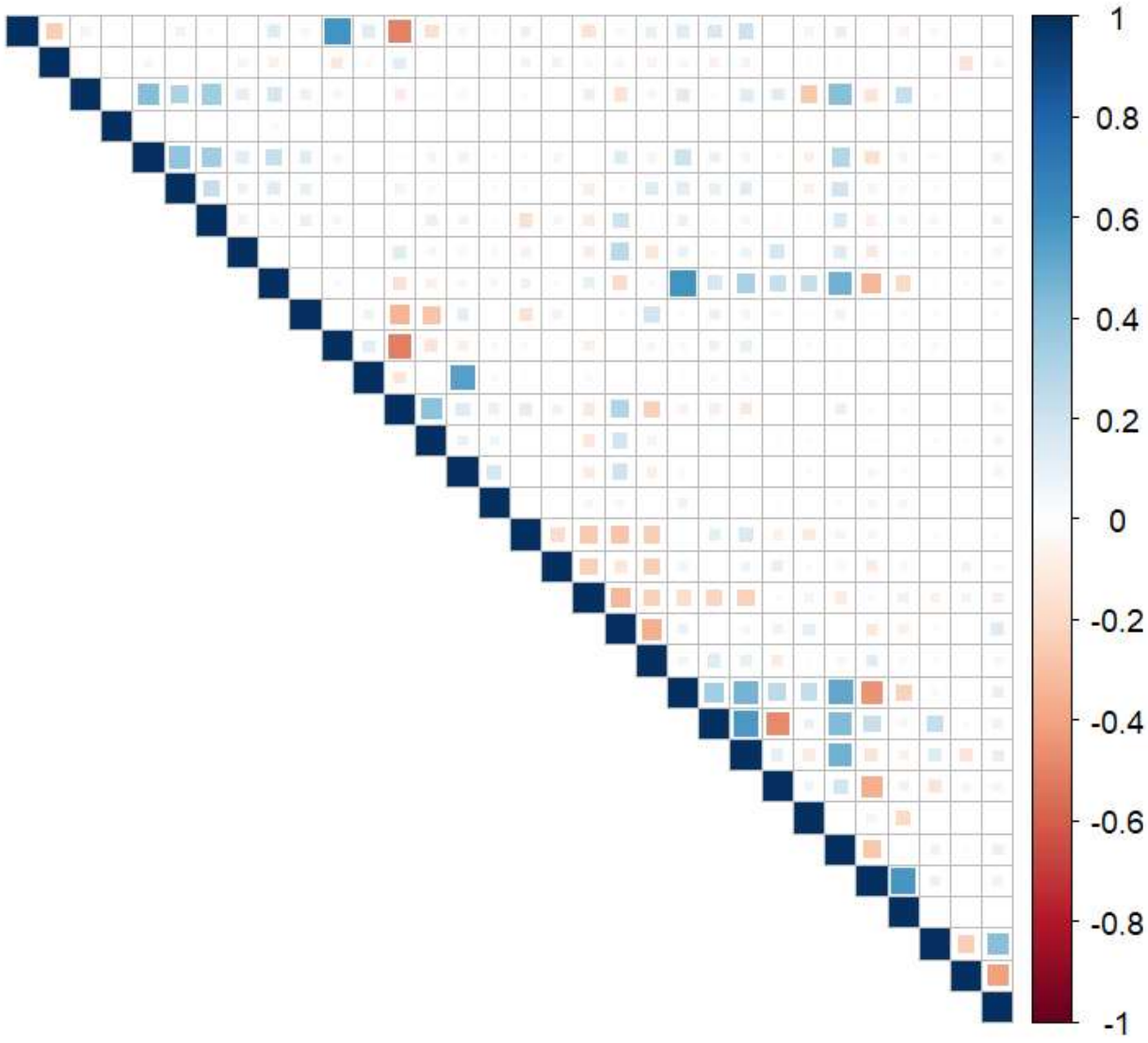
```
names(X.non.bi)[high.cor.non.bi]
```

```
 [1] "rate_positive_words"       "avg_positive_polarity"
 [3] "kw_avg_avg"                "min_negative_polarity"
 [5] "rate_negative_words"       "kw_max_max"
 [7] "title_subjectivity"        "self_reference_max_shares"
 [9] "kw_max_min"                "n_non_stop_words"
[11] "self_reference_min_shares" "n_unique_tokens"
```

12 variables contribute to high pairwise correlation between the non-binary predictors. Let's remove them

Hide

```
X.non.bi <- X.non.bi[, -high.cor.non.bi]
cor.non.bi.filtered <- cor(X.non.bi)
corrplot(
  cor.non.bi.filtered,
  method = "square",
  type = "upper",
  tl.pos = "n"
)
```



Let’s update our master predictor matrix to only retain the non-problematic predictors.

Hide

```
cols.to.keep <- c(names(X.bi), names(X.non.bi))
X <- X[, names(X) %in% cols.to.keep]
```

Split the Data

Hide

```
set.seed(100)
train.rows <- createDataPartition(y, p = .8, list = FALSE)
y.train <- y[train.rows]
y.test <- y[-train.rows]
X.train <- X[train.rows, ]
X.test <- X[-train.rows, ]
idx <- createFolds(y.train, returnTrain = TRUE)
ctrl <- trainControl(method = "cv", index = idx)
```

Modeling

Linear Models

Elastic Net

Hide

```
enetGrid <- expand.grid(lambda = c(0, 0.01, .1),
                        fraction = seq(0, 1, length = 10))
set.seed(100)
enet <- train(x = X.train, y = y.train,
                         method = "enet",
                         tuneGrid = enetGrid,
                         trControl = ctrl,
                         preProc = c("center", "scale"))
```

```
Warning in nominalTrainWorkflow(x = x, y = y, wts = weights, info = trainInfo,  :
  There were missing values in resampled performance measures.
```

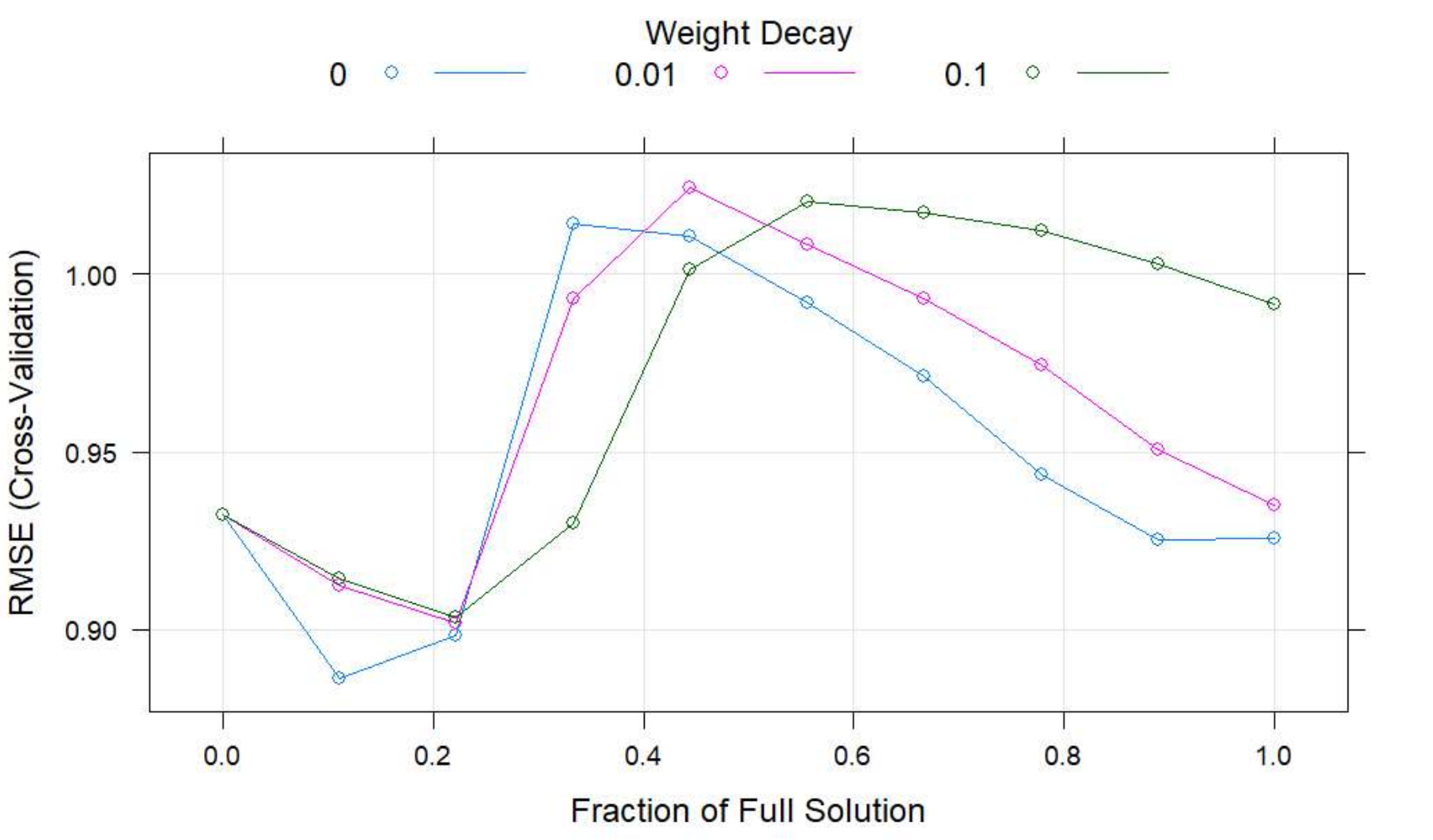
Hide

```
enet
```

```
Elasticnet

31716 samples
   44 predictor

Pre-processing: centered (44), scaled (44)
Resampling: Cross-Validated (10 fold)
Summary of sample sizes: 28545, 28543, 28544, 28545, 28545, 28543, ...
Resampling results across tuning parameters:

  lambda  fraction   RMSE       Rsquared    MAE
  0.00    0.0000000  0.9321901         NaN  0.7055694
  0.00    0.1111111  0.8864478  0.09719415  0.6583323
  0.00    0.2222222  0.8984610  0.09224848  0.6581408
  0.00    0.3333333  1.0141256  0.09176563  0.6601719
  0.00    0.4444444  1.0105262  0.09178231  0.6597225
  0.00    0.5555556  0.9917711  0.09181401  0.6591108
  0.00    0.6666667  0.9714230  0.09187086  0.6585251
  0.00    0.7777778  0.9437185  0.09203142  0.6578012
  0.00    0.8888889  0.9253482  0.09228926  0.6573308
  0.00    1.0000000  0.9255977  0.09228056  0.6573320
  0.01    0.0000000  0.9321901         NaN  0.7055694
  0.01    0.1111111  0.9124461  0.06195643  0.6876086
  0.01    0.2222222  0.9020839  0.07603802  0.6761242
  0.01    0.3333333  0.9930125  0.07909097  0.6712378
  0.01    0.4444444  1.0242694  0.08325657  0.6672900
  0.01    0.5555556  1.0084331  0.08667635  0.6639962
  0.01    0.6666667  0.9932545  0.08918634  0.6617399
  0.01    0.7777778  0.9742261  0.09087545  0.6599432
  0.01    0.8888889  0.9506518  0.09180482  0.6584963
  0.01    1.0000000  0.9352032  0.09208036  0.6576853
  0.10    0.0000000  0.9321901         NaN  0.7055694
  0.10    0.1111111  0.9144814  0.05737692  0.6895019
  0.10    0.2222222  0.9034129  0.07577590  0.6787493
  0.10    0.3333333  0.9301465  0.07640761  0.6725192
  0.10    0.4444444  1.0012548  0.08049357  0.6692252
  0.10    0.5555556  1.0204530  0.08394508  0.6662717
  0.10    0.6666667  1.0174417  0.08655568  0.6638276
  0.10    0.7777778  1.0120269  0.08835610  0.6620833
  0.10    0.8888889  1.0030191  0.08960134  0.6607376
  0.10    1.0000000  0.9915162  0.09028498  0.6597427

RMSE was used to select the optimal model using the smallest value.
The final values used for the model were fraction = 0.1111111 and lambda = 0.
```

Hide

```
plot(enet)
```



Hide

```
library(Metrics)
pred.enet <- predict(enet, X.test)
resid.enet <- y.test - pred.enet
rmse(y.test, pred.enet)
```

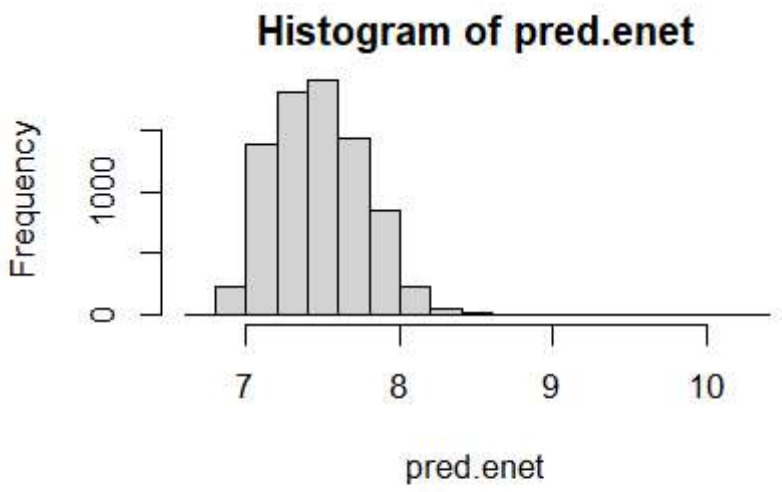
```
[1] 0.8736786
```

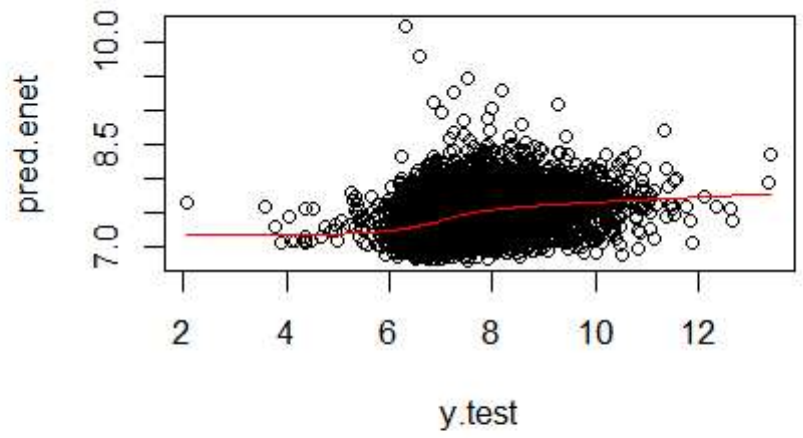
Hide

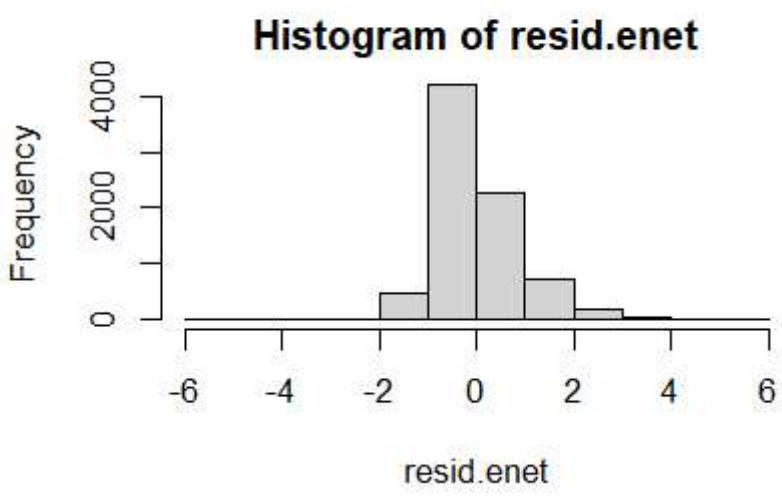
```
par(mfrow = c(2, 2))
hist(pred.enet)
plot(y.test, pred.enet)
```

Hide

```
lines(lowess(y.test, pred.enet), col = "red")
hist(resid.enet)
```

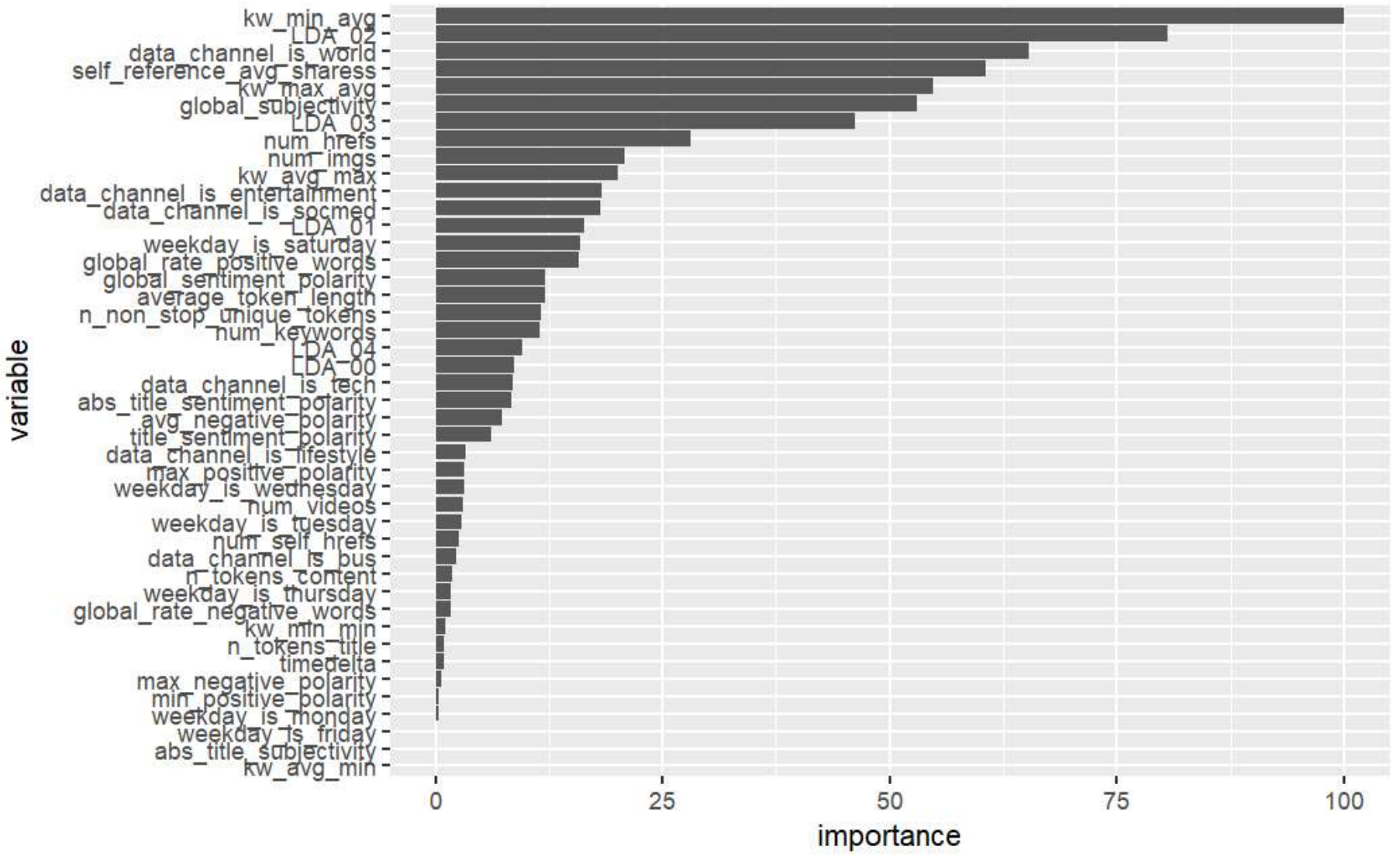






Hide

```
library(tidyr)
library(dplyr)
plot.var.imp <- function(model) {
  imp <- varImp(model)$importance
  names(imp) <- "importance"
  df <- imp %>%
    tibble::rownames_to_column() %>%
    dplyr::rename("variable" = rowname) %>%
    dplyr::arrange(importance) %>%
    dplyr::mutate(variable = forcats::fct_inorder(variable))
  ggplot(df) +
    geom_col(aes(x = variable, y = importance)) +
    coord_flip()
}
plot.var.imp(enet)
```



Principal Component Regression (PCR)

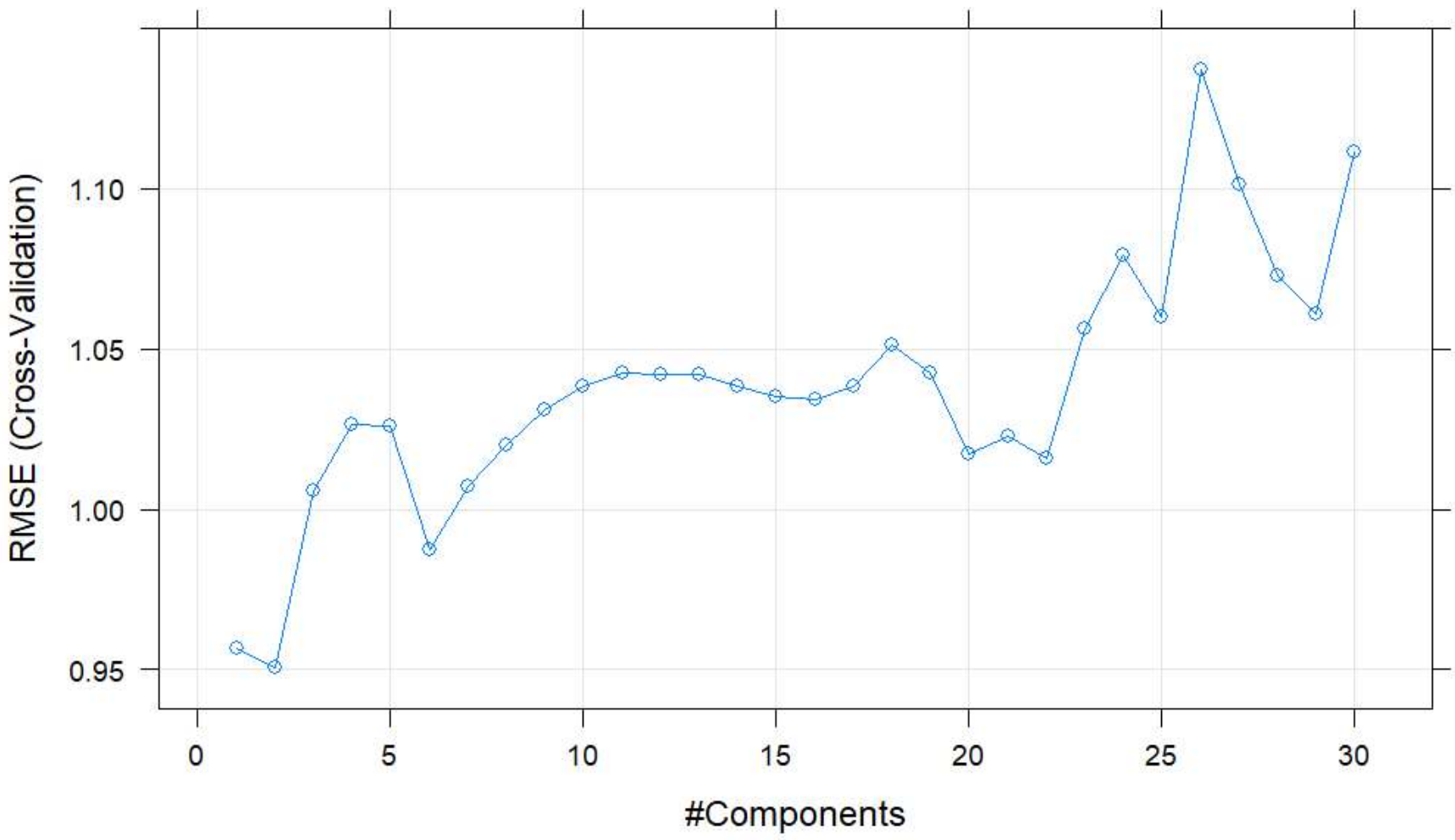
Hide

```
set.seed(100)
pcr <- train(
  x = X.train,
  y = y.train,
  preProc = c("center", "scale"),
  method = "pcr",
  tuneGrid = expand.grid(ncomp = 1:30),
  trControl = ctrl
)
pcr
```

```
Principal Component Analysis

31716 samples
   44 predictor

Pre-processing: centered (44), scaled (44)
Resampling: Cross-Validated (10 fold)
Summary of sample sizes: 28545, 28543, 28544, 28545, 28545, 28543, ...
Resampling results across tuning parameters:

  ncomp  RMSE       Rsquared    MAE
   1     0.9564855  0.01178708  0.6999365
   2     0.9506298  0.01371925  0.7006422
   3     1.0055397  0.02027480  0.6970122
   4     1.0264125  0.03108140  0.6935467
   5     1.0258371  0.03710015  0.6902230
   6     0.9872631  0.03973736  0.6891277
   7     1.0072425  0.05075586  0.6836527
   8     1.0197577  0.06103294  0.6775825
   9     1.0310467  0.06189408  0.6769297
  10     1.0383555  0.06427197  0.6760569
  11     1.0425336  0.06435240  0.6760535
  12     1.0421863  0.06436422  0.6760670
  13     1.0419949  0.06435685  0.6760890
  14     1.0385274  0.06455183  0.6759535
  15     1.0353205  0.06469239  0.6757173
  16     1.0343919  0.06572786  0.6746489
  17     1.0384508  0.06716957  0.6735439
  18     1.0513084  0.06916830  0.6725950
  19     1.0424204  0.06925672  0.6722834
  20     1.0171999  0.06929440  0.6717861
  21     1.0226609  0.07085403  0.6712181
  22     1.0156971  0.07082380  0.6711018
  23     1.0563385  0.07131937  0.6715888
  24     1.0791325  0.07329755  0.6707452
  25     1.0598179  0.07402953  0.6700027
  26     1.1370649  0.07432287  0.6709589
  27     1.1013242  0.07903175  0.6679192
  28     1.0725556  0.08054003  0.6667135
  29     1.0606241  0.08064363  0.6663973
  30     1.1111882  0.08255071  0.6665347

RMSE was used to select the optimal model using the smallest value.
The final value used for the model was ncomp = 2.
```

Hide

```
plot(pcr)
```



Hide

```
pred.pcr <- predict(pcr, X.test)
resid.pcr <- y.test - pred.pcr
rmse(y.test, pred.pcr)
```

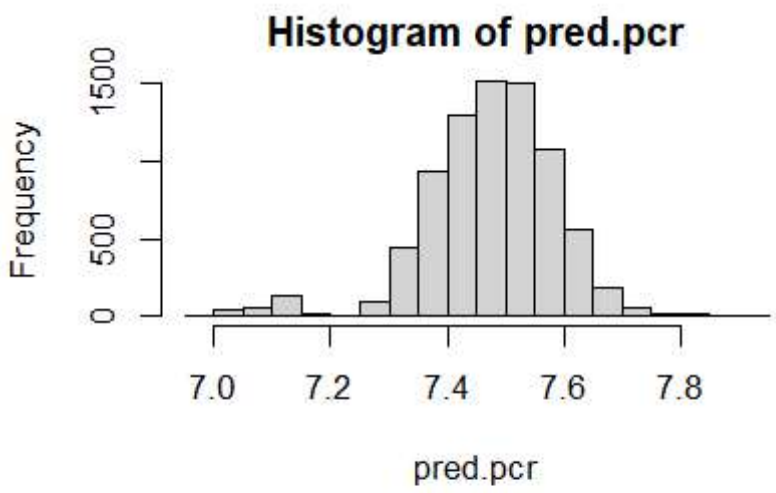
```
[1] 0.9152851
```

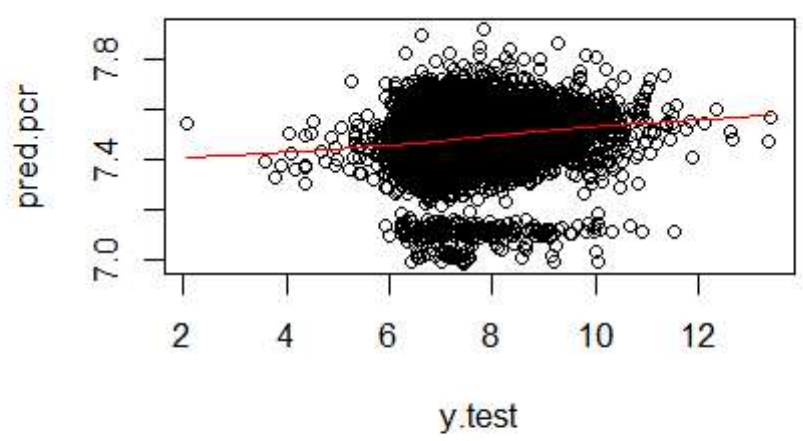
Hide

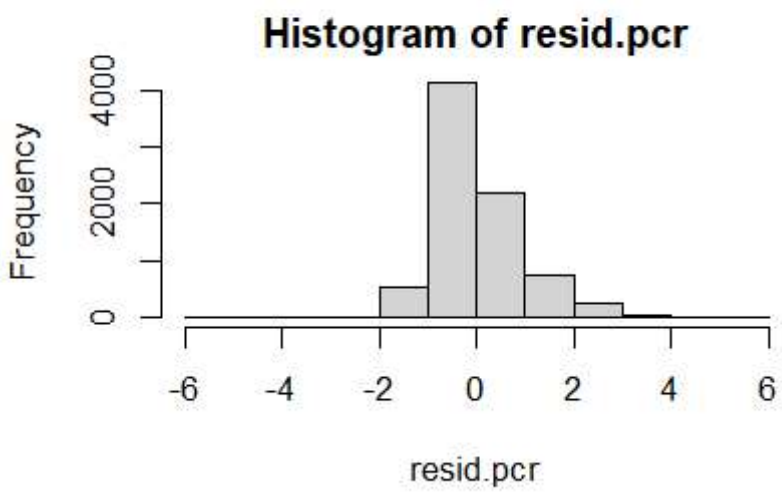
```
par(mfrow = c(2, 2))
hist(pred.pcr)
plot(y.test, pred.pcr)
```

Hide

```
lines(lowess(y.test, pred.pcr), col = "red")
hist(resid.pcr)
```

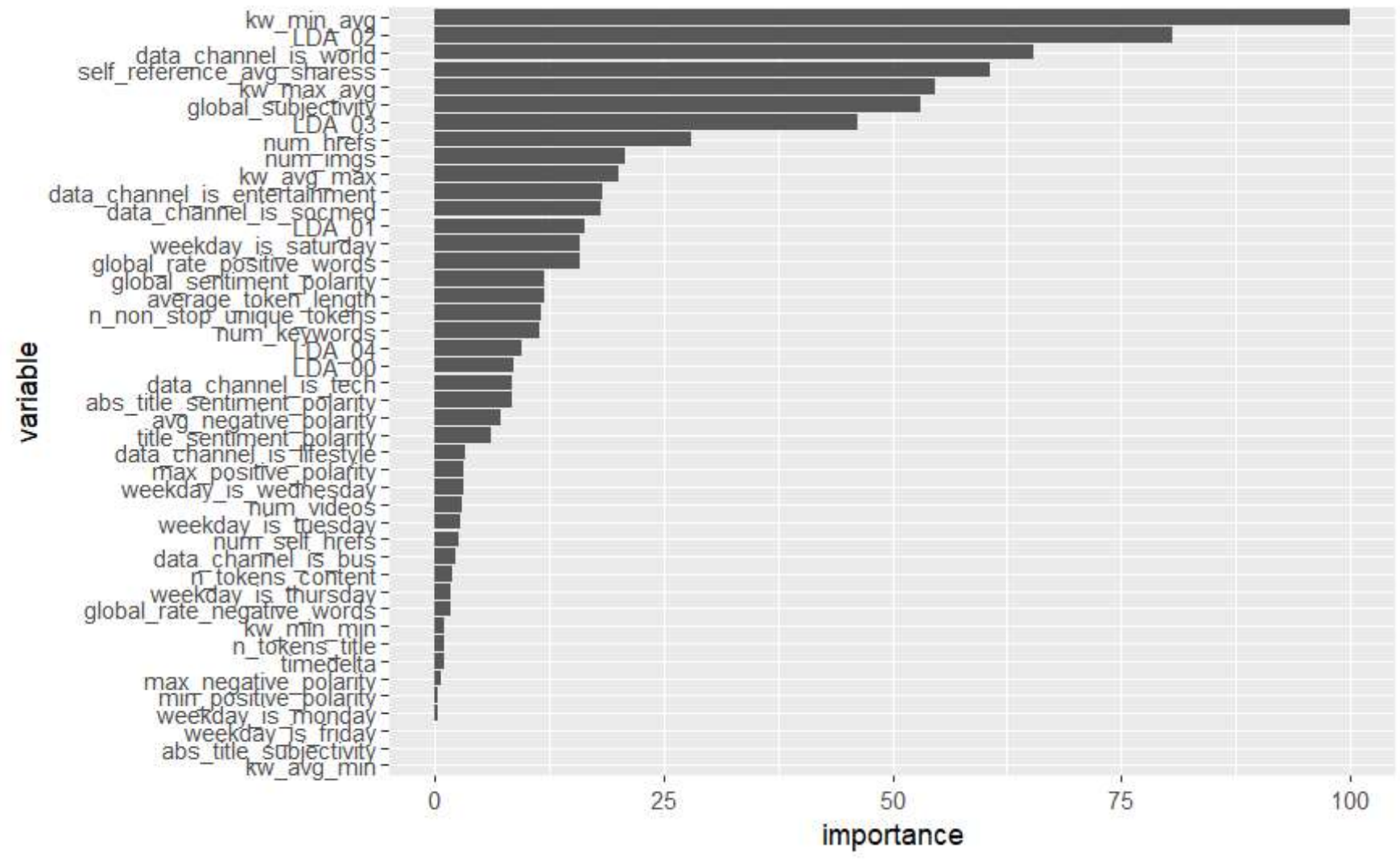






Hide

```
plot.var.imp(pcr)
```



Principal Least Squares (PLS)

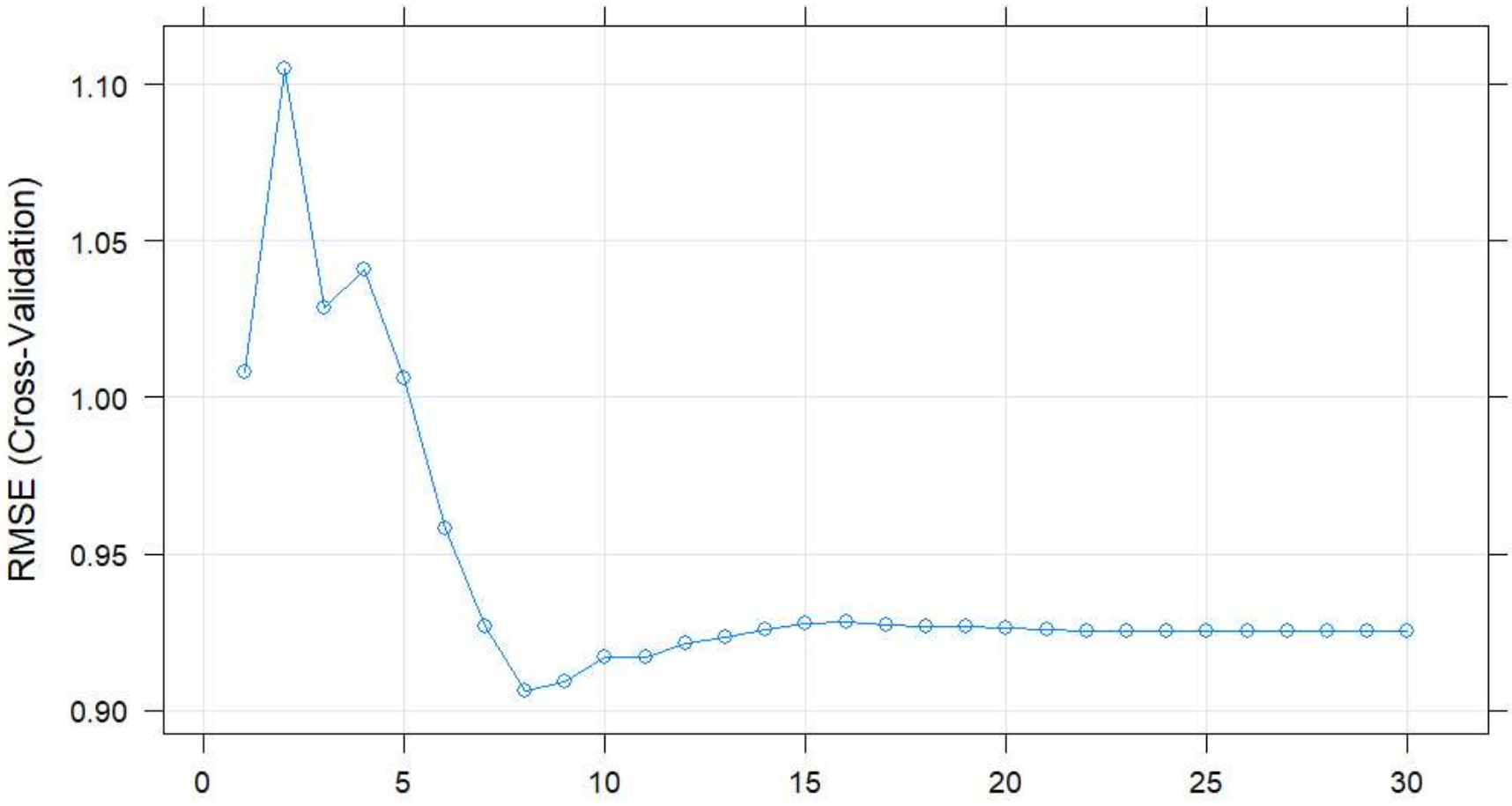
Hide

```
set.seed(100)
pls <- train(
  x = X.train,
  y = y.train,
  preProc = c("center", "scale"),
  method = "pls",
  tuneGrid = expand.grid(ncomp = 1:30),
  trControl = ctrl
)
pls
```

```
Partial Least Squares

31716 samples
   44 predictor

Pre-processing: centered (44), scaled (44)
Resampling: Cross-Validated (10 fold)
Summary of sample sizes: 28545, 28543, 28544, 28545, 28545, 28543, ...
Resampling results across tuning parameters:

  ncomp  RMSE       Rsquared    MAE
   1     1.0081791  0.07008790  0.6725356
   2     1.1050275  0.08177957  0.6672321
   3     1.0287718  0.08596654  0.6621882
   4     1.0406781  0.08813904  0.6619958
   5     1.0062603  0.08918816  0.6604577
   6     0.9580051  0.08998082  0.6593843
   7     0.9269833  0.09102492  0.6577060
   8     0.9061434  0.09218942  0.6572565
   9     0.9091684  0.09232601  0.6571385
  10     0.9168351  0.09231033  0.6572566
  11     0.9169095  0.09238749  0.6571904
  12     0.9212655  0.09232177  0.6573581
  13     0.9233782  0.09230921  0.6573563
  14     0.9255953  0.09226908  0.6574269
  15     0.9278961  0.09220801  0.6574667
  16     0.9280959  0.09221487  0.6574630
  17     0.9274290  0.09223820  0.6574367
  18     0.9269394  0.09225409  0.6574205
  19     0.9268117  0.09225790  0.6574163
  20     0.9262709  0.09226743  0.6574045
  21     0.9257207  0.09227697  0.6573907
  22     0.9254667  0.09228171  0.6573851
  23     0.9252826  0.09228470  0.6573812
  24     0.9251623  0.09228687  0.6573780
  25     0.9251541  0.09228683  0.6573780
  26     0.9251689  0.09228654  0.6573783
  27     0.9251916  0.09228610  0.6573788
  28     0.9252020  0.09228594  0.6573791
  29     0.9252086  0.09228577  0.6573793
  30     0.9252110  0.09228584  0.6573792

RMSE was used to select the optimal model using the smallest value.
The final value used for the model was ncomp = 8.
```

Hide

```
plot(pls)
```



Hide

```
pred.pls <- predict(pls, X.test)
resid.pls <- y.test - pred.pls
rmse(y.test, pred.pls)
```

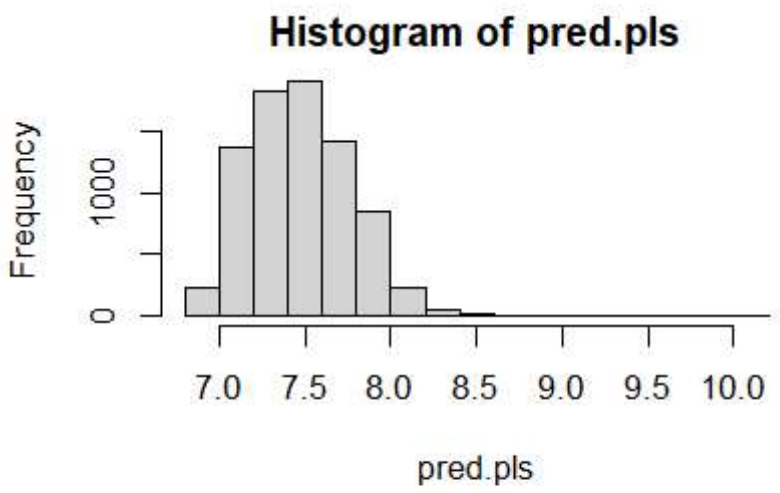
```
[1] 0.8735161
```

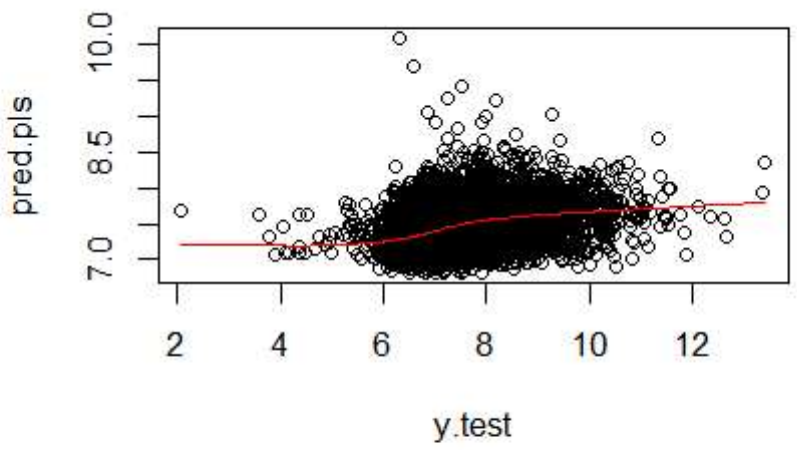
Hide

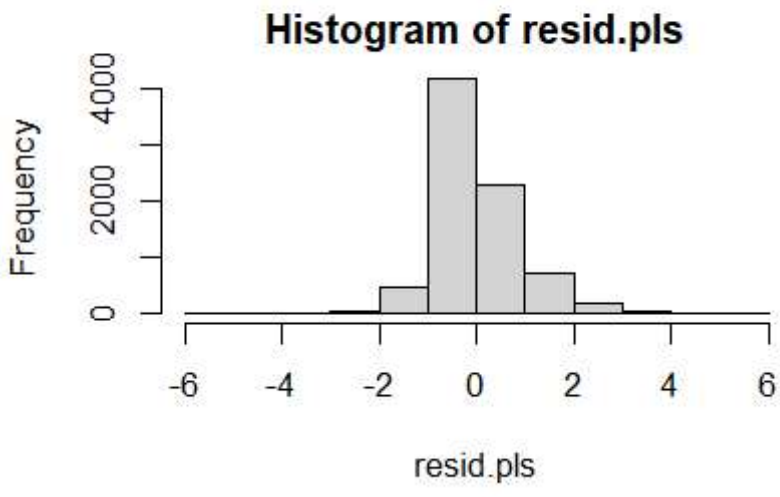
```
par(mfrow = c(2, 2))
hist(pred.pls)
plot(y.test, pred.pls)
```

Hide

```
lines(lowess(y.test, pred.pls), col = "red")
hist(resid.pls)
```

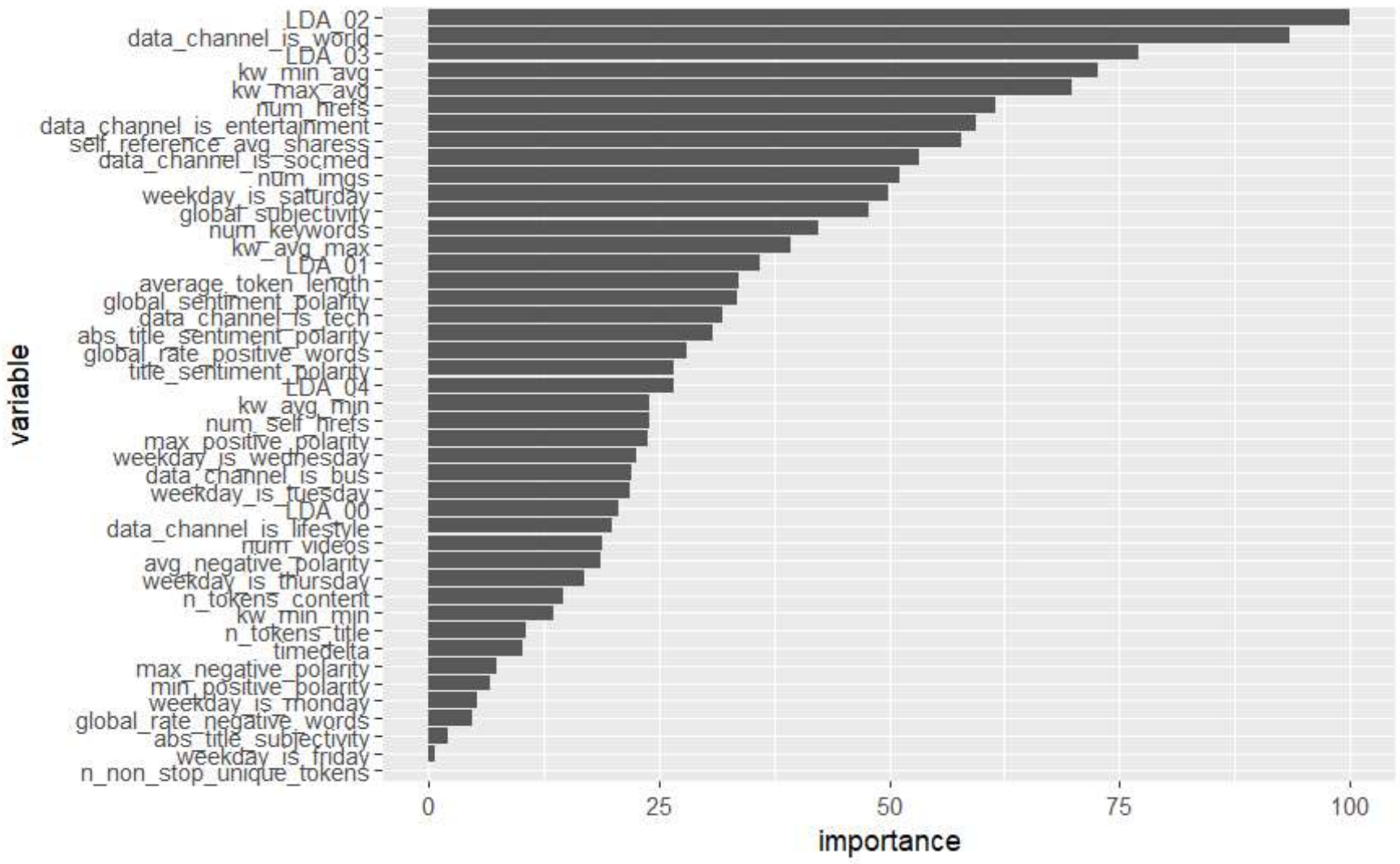






Hide

```
plot.var.imp(pls)
```



Non-Linear Models

K-Nearest Neighbors (k-NN)

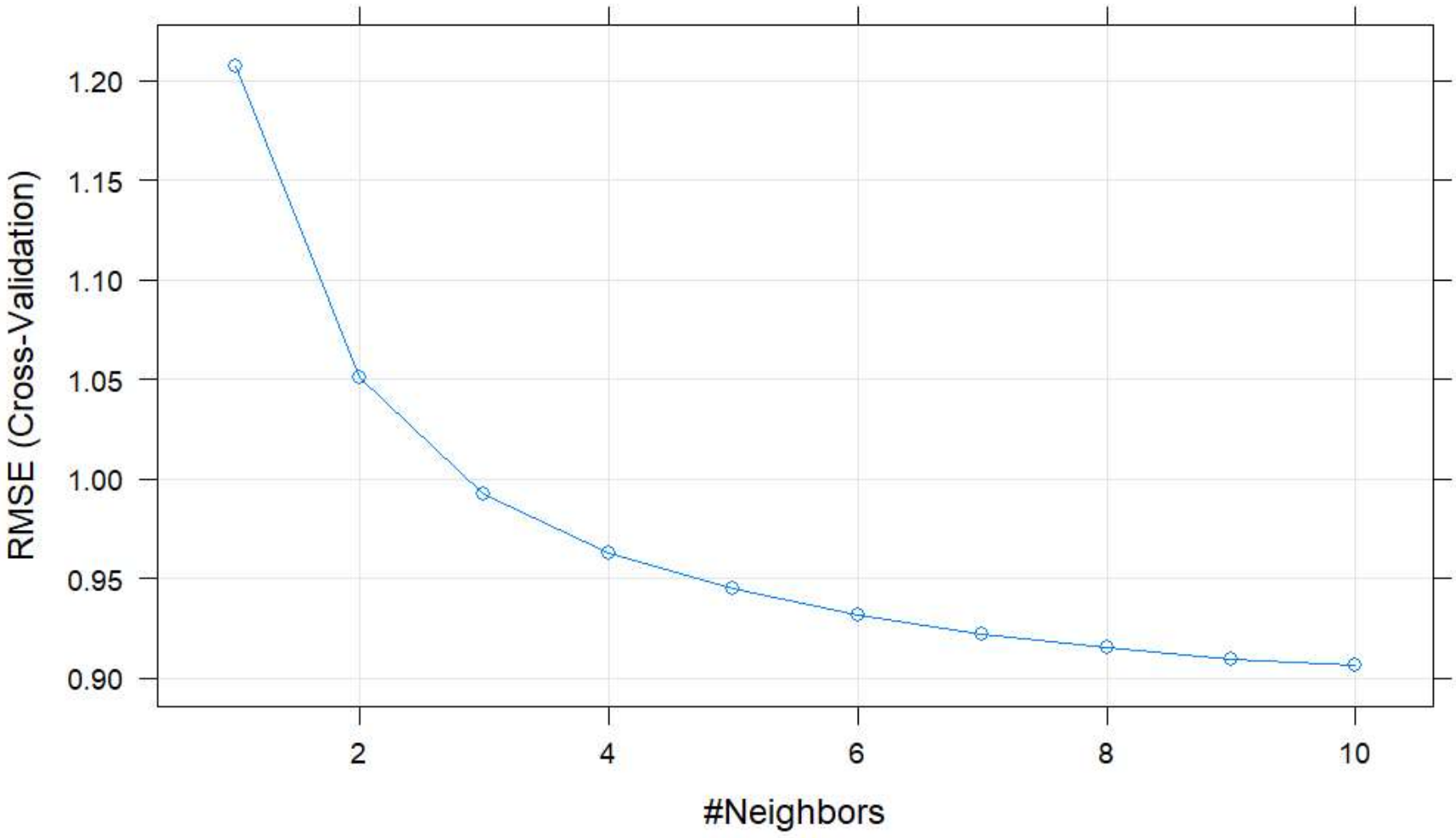
Hide

```
set.seed(100)
knn <- train(
  x = X.train,
  y = y.train,
  preProc = c("center", "scale"),
  method = "knn",
  tuneGrid = expand.grid(k = 1:10),
  trControl = ctrl
)
knn
```

```
k-Nearest Neighbors

31716 samples
   44 predictor

Pre-processing: centered (44), scaled (44)
Resampling: Cross-Validated (10 fold)
Summary of sample sizes: 28545, 28543, 28544, 28545, 28545, 28543, ...
Resampling results across tuning parameters:

  k   RMSE       Rsquared    MAE
   1  1.2072226  0.02173822  0.8848739
   2  1.0509486  0.03416209  0.7788457
   3  0.9922019  0.04473664  0.7359284
   4  0.9623583  0.05301447  0.7129060
   5  0.9447195  0.05963674  0.6985403
   6  0.9311917  0.06663565  0.6866949
   7  0.9219106  0.07177303  0.6787405
   8  0.9153567  0.07573898  0.6731041
   9  0.9095756  0.08010333  0.6678407
  10  0.9062993  0.08204549  0.6646600

RMSE was used to select the optimal model using the smallest value.
The final value used for the model was k = 10.
```

Hide

```
plot(knn)
```



Hide

```
pred.knn <- predict(knn, X.test)
resid.knn <- y.test - pred.knn
rmse(y.test, pred.knn)
```

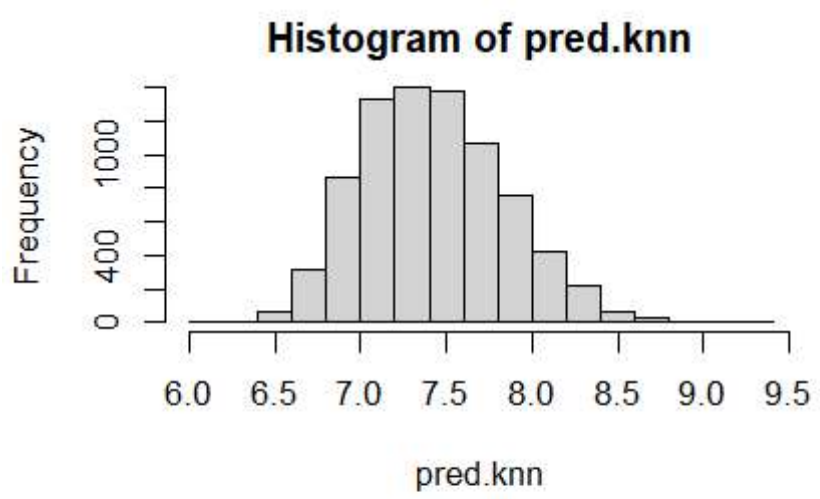
```
[1] 0.9015301
```

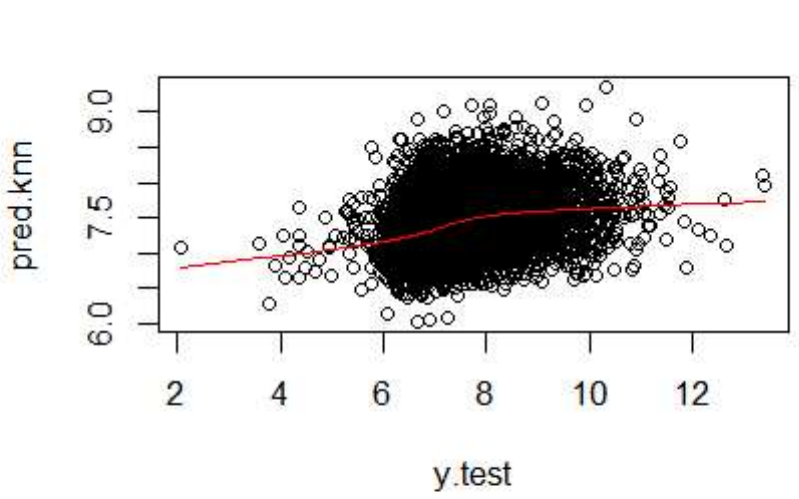
Hide

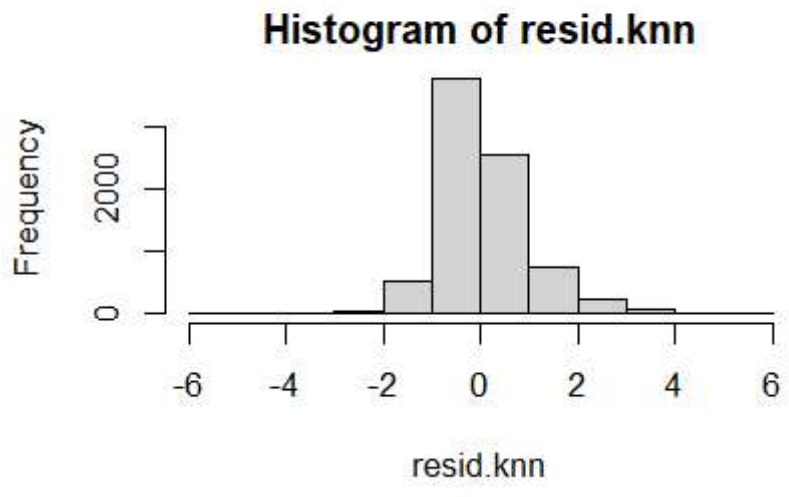
```
par(mfrow = c(2, 2))
hist(pred.knn)
plot(y.test, pred.knn)
```

Hide

```
lines(lowess(y.test, pred.knn), col = "red")
hist(resid.knn)
```

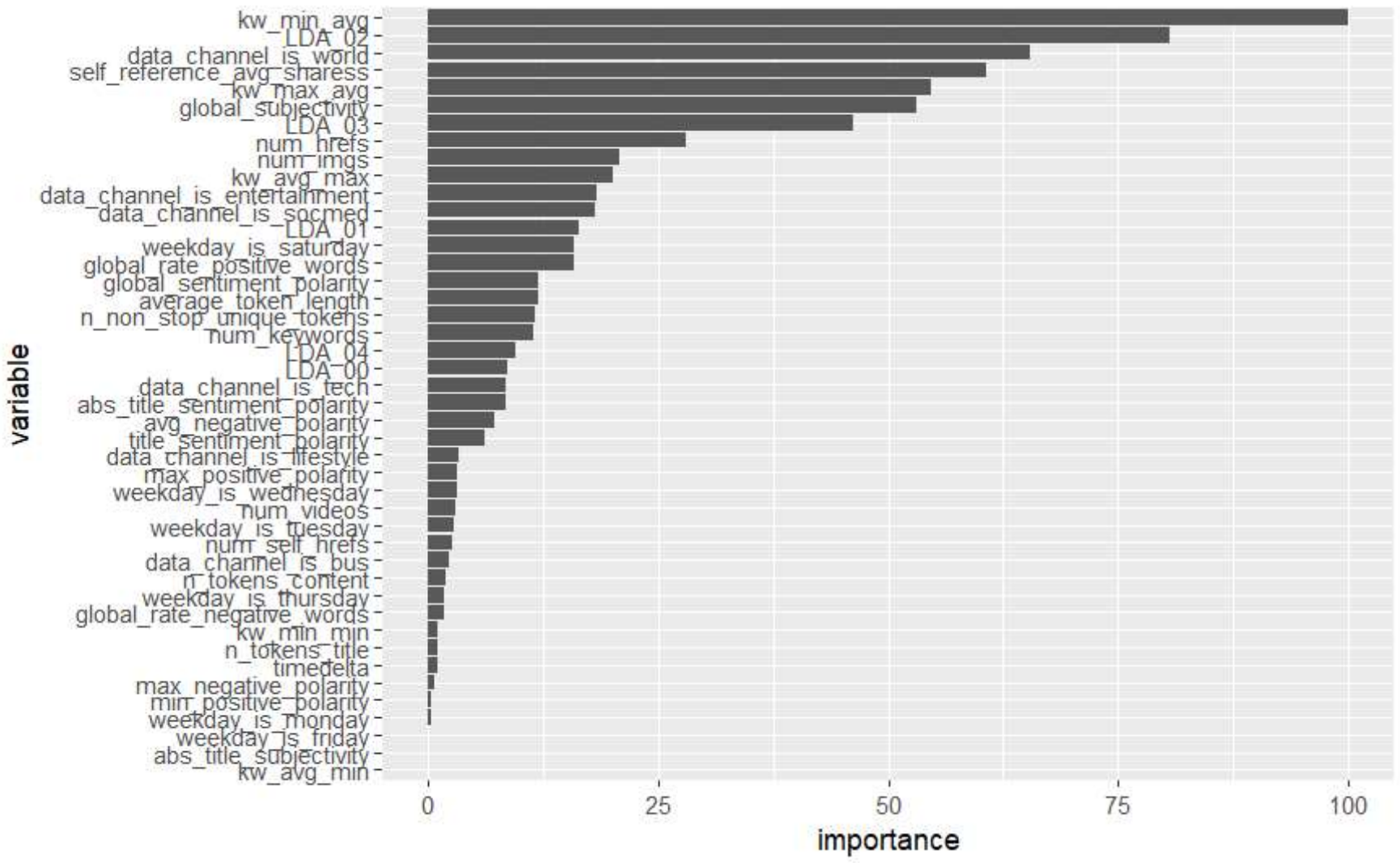






Hide

```
plot.var.imp(knn)
```



Classification and Regression Tree (CART)

Hide

```
set.seed(100)
cart <- train(
  x = X.train,
  y = y.train,
  preProc = c("center", "scale"),
  method = "rpart",
  tuneGrid = expand.grid(cp = seq(0.001, 0.1, 0.01))
)
```

```
Warning in nominalTrainWorkflow(x = x, y = y, wts = weights, info = trainInfo,  :
  There were missing values in resampled performance measures.
```

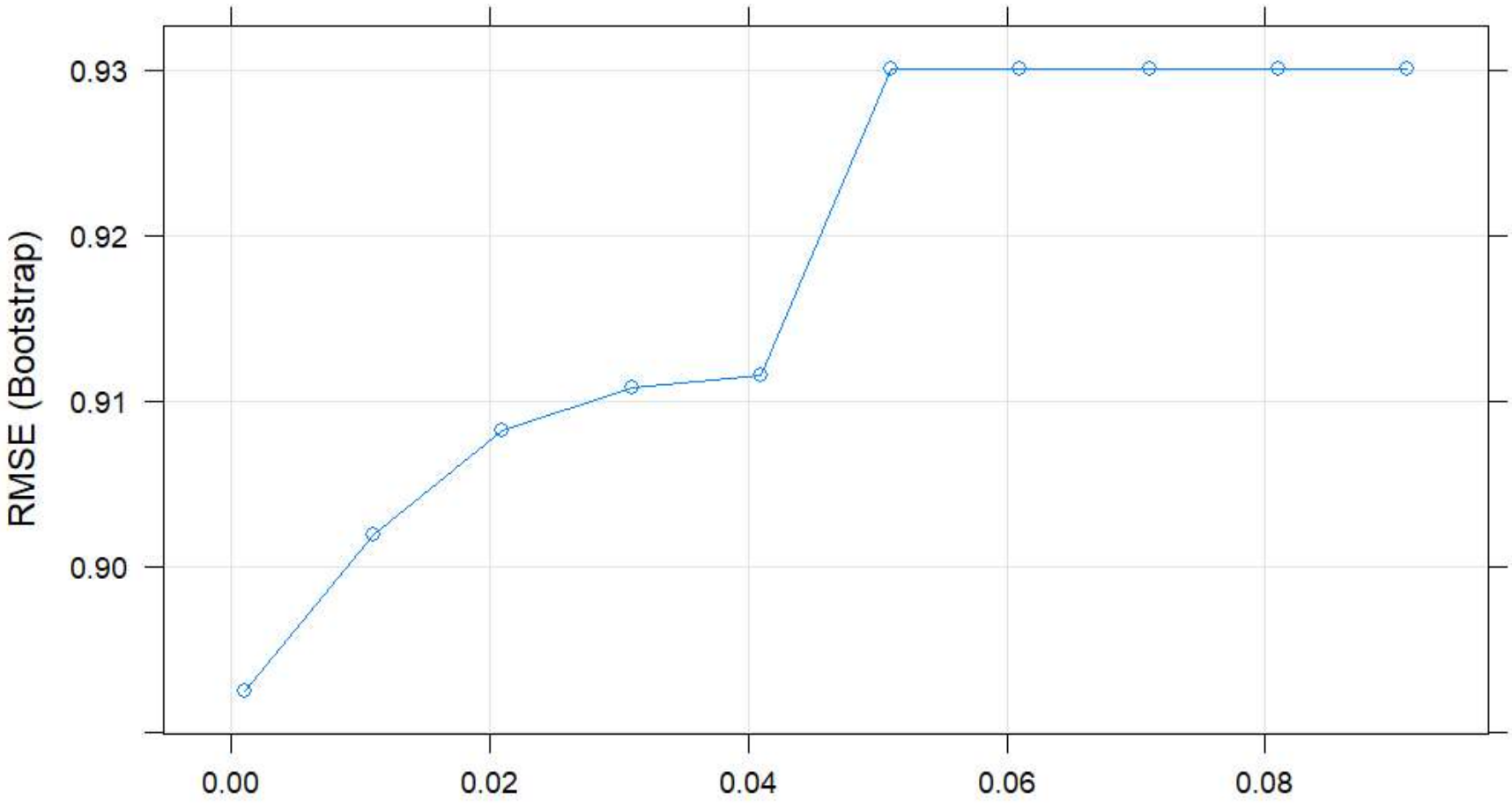
Hide

```
cart
```

```
CART

31716 samples
   44 predictor

Pre-processing: centered (44), scaled (44)
Resampling: Bootstrapped (25 reps)
Summary of sample sizes: 31716, 31716, 31716, 31716, 31716, 31716, ...
Resampling results across tuning parameters:

  cp     RMSE       Rsquared    MAE
  0.001  0.8924639  0.08998393  0.6621639
  0.011  0.9019196  0.05988036  0.6800254
  0.021  0.9081914  0.04668786  0.6855366
  0.031  0.9107644  0.04119749  0.6878669
  0.041  0.9115580  0.04114349  0.6885583
  0.051  0.9300558         NaN  0.7044480
  0.061  0.9300558         NaN  0.7044480
  0.071  0.9300558         NaN  0.7044480
  0.081  0.9300558         NaN  0.7044480
  0.091  0.9300558         NaN  0.7044480

RMSE was used to select the optimal model using the smallest value.
The final value used for the model was cp = 0.001.
```

Hide

```
plot(cart)
```



Hide

```
pred.cart <- predict(cart, X.test)
resid.cart <- y.test - pred.cart
rmse(y.test, pred.cart)
```

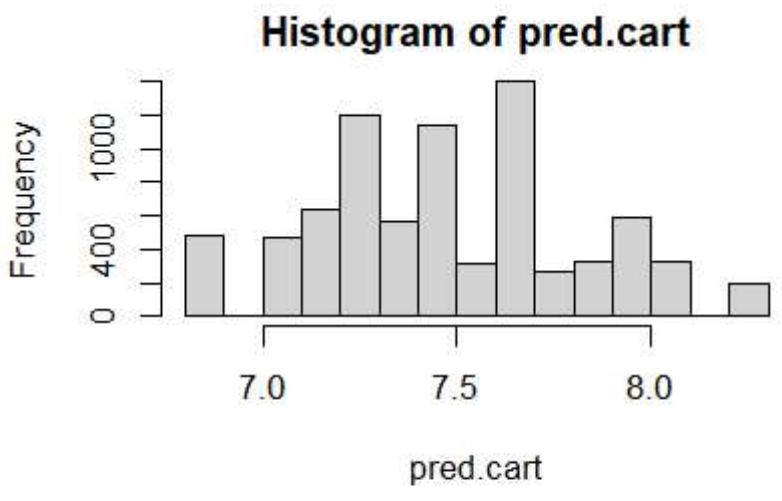
```
[1] 0.8773104
```

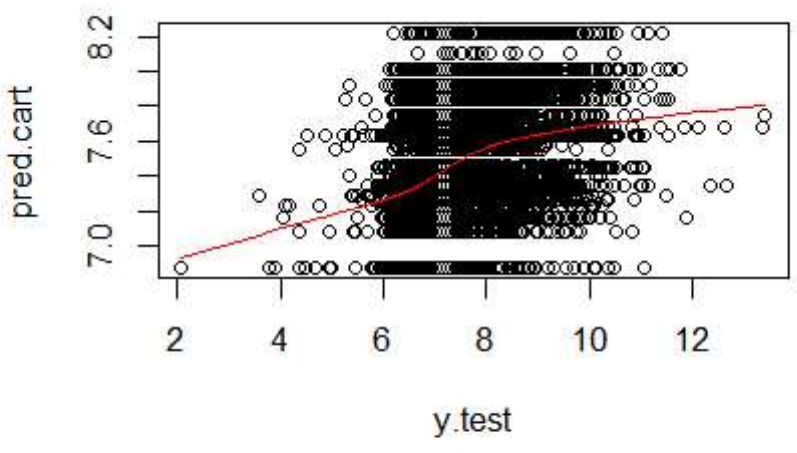
Hide

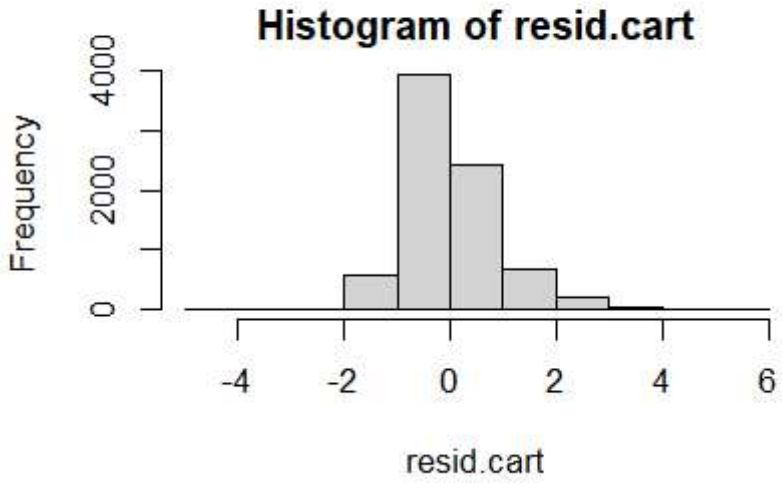
```
par(mfrow = c(2, 2))
hist(pred.cart)
plot(y.test, pred.cart)
```

Hide

```
lines(lowess(y.test, pred.cart), col = "red")
hist(resid.cart)
```

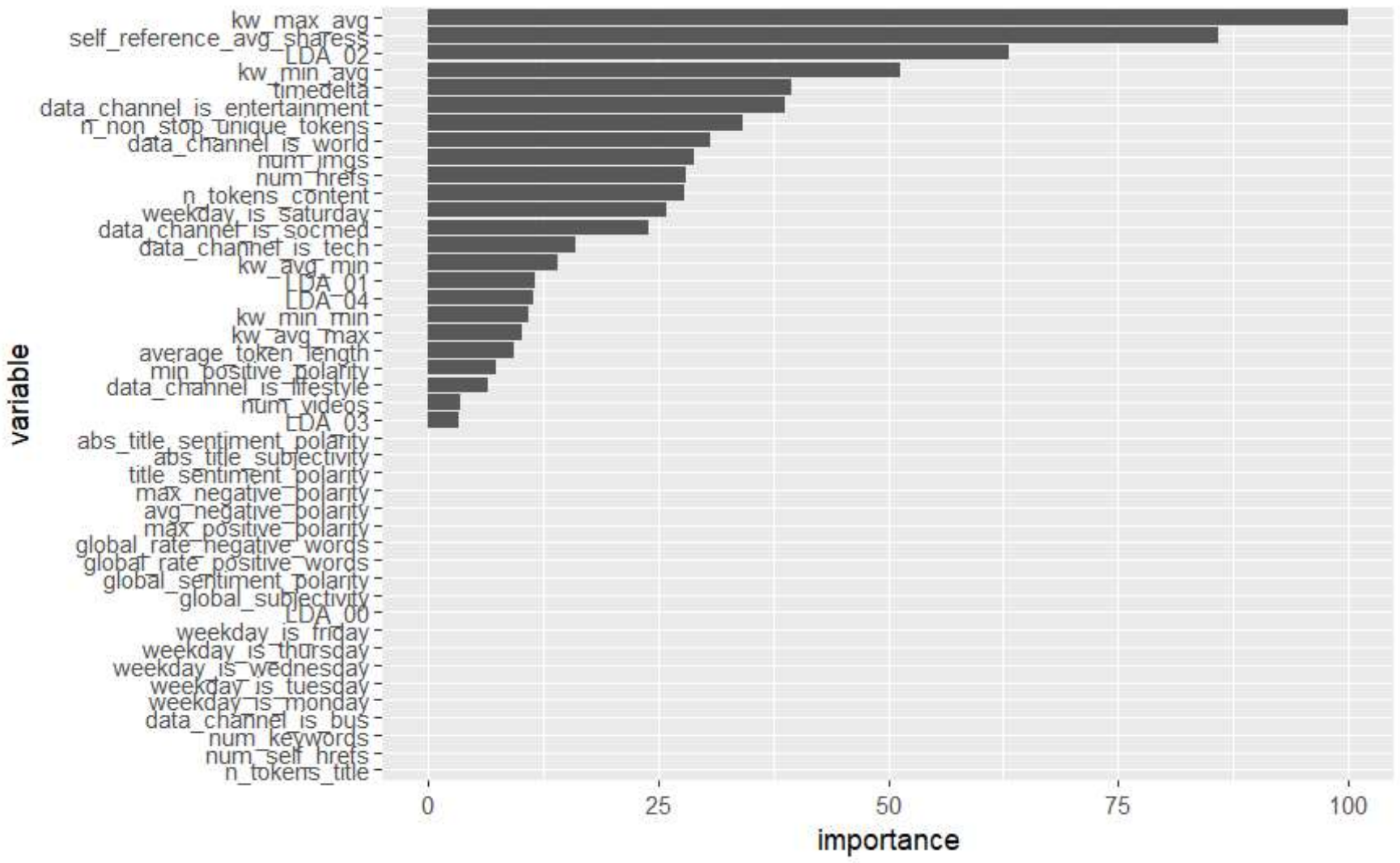






Hide

```
plot.var.imp(cart)
```



Stochastic Gradient Boosting

Hide

```
set.seed(100)
gbm.grid <- expand.grid(n.trees = 100, interaction.depth = 1:5, shrinkage = c(0.01, 0.1), n.minobsinnode = 10)
gbm <- train(
  x = X.train,
  y = y.train,
  trControl = ctrl,
  preProc = c("center", "scale"),
  method = "gbm",
  tuneGrid = gbm.grid
)
```

```
Iter   TrainDeviance   ValidDeviance   StepSize   Improve
     1        0.8679             nan     0.0100    0.0008
     2        0.8671             nan     0.0100    0.0007
     3        0.8664             nan     0.0100    0.0007
     4        0.8657             nan     0.0100    0.0007
     5        0.8650             nan     0.0100    0.0007
     6        0.8643             nan     0.0100    0.0007
     7        0.8637             nan     0.0100    0.0007
     8        0.8630             nan     0.0100    0.0006
     9        0.8623             nan     0.0100    0.0006
    10        0.8617             nan     0.0100    0.0006
    20        0.8558             nan     0.0100    0.0006
    40        0.8457             nan     0.0100    0.0004
    60        0.8373             nan     0.0100    0.0004
    80        0.8303             nan     0.0100    0.0003
   100        0.8242             nan     0.0100    0.0003

Iter   TrainDeviance   ValidDeviance   StepSize   Improve
     1        0.8675             nan     0.0100    0.0011
     2        0.8665             nan     0.0100    0.0011
     3        0.8654             nan     0.0100    0.0011
     4        0.8643             nan     0.0100    0.0010
     5        0.8633             nan     0.0100    0.0010
     6        0.8624             nan     0.0100    0.0009
     7        0.8615             nan     0.0100    0.0009
     8        0.8606             nan     0.0100    0.0009
     9        0.8596             nan     0.0100    0.0009
    10        0.8588             nan     0.0100    0.0008
    20        0.8505             nan     0.0100    0.0007
    40        0.8371             nan     0.0100    0.0005
    60        0.8267             nan     0.0100    0.0005
    80        0.8180             nan     0.0100    0.0004
   100        0.8108             nan     0.0100    0.0003

Iter   TrainDeviance   ValidDeviance   StepSize   Improve
     1        0.8674             nan     0.0100    0.0012
     2        0.8662             nan     0.0100    0.0012
     3        0.8650             nan     0.0100    0.0011
     4        0.8639             nan     0.0100    0.0011
     5        0.8627             nan     0.0100    0.0011
     6        0.8616             nan     0.0100    0.0011
     7        0.8605             nan     0.0100    0.0011
     8        0.8594             nan     0.0100    0.0011
     9        0.8583             nan     0.0100    0.0011
    10        0.8573             nan     0.0100    0.0010
    20        0.8478             nan     0.0100    0.0009
    40        0.8324             nan     0.0100    0.0007
    60        0.8203             nan     0.0100    0.0005
    80        0.8106             nan     0.0100    0.0004
   100        0.8023             nan     0.0100    0.0003

Iter   TrainDeviance   ValidDeviance   StepSize   Improve
     1        0.8673             nan     0.0100    0.0013
     2        0.8659             nan     0.0100    0.0013
     3        0.8646             nan     0.0100    0.0012
     4        0.8634             nan     0.0100    0.0013
     5        0.8622             nan     0.0100    0.0012
     6        0.8610             nan     0.0100    0.0012
     7        0.8597             nan     0.0100    0.0012
     8        0.8586             nan     0.0100    0.0011
     9        0.8575             nan     0.0100    0.0011
    10        0.8563             nan     0.0100    0.0011
    20        0.8459             nan     0.0100    0.0009
    40        0.8290             nan     0.0100    0.0007
    60        0.8160             nan     0.0100    0.0005
    80        0.8053             nan     0.0100    0.0005
   100        0.7966             nan     0.0100    0.0004

Iter   TrainDeviance   ValidDeviance   StepSize   Improve
     1        0.8672             nan     0.0100    0.0014
     2        0.8658             nan     0.0100    0.0014
     3        0.8645             nan     0.0100    0.0013
     4        0.8632             nan     0.0100    0.0013
     5        0.8619             nan     0.0100    0.0013
     6        0.8606             nan     0.0100    0.0013
     7        0.8593             nan     0.0100    0.0012
     8        0.8580             nan     0.0100    0.0012
     9        0.8568             nan     0.0100    0.0012
    10        0.8555             nan     0.0100    0.0012
    20        0.8445             nan     0.0100    0.0010
    40        0.8265             nan     0.0100    0.0008
    60        0.8125             nan     0.0100    0.0006
    80        0.8015             nan     0.0100    0.0004
```

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   100        0.7924             nan     0.0100    0.0004

Iter   TrainDeviance   ValidDeviance   StepSize   Improve
     1        0.8612             nan     0.1000    0.0072
     2        0.8554             nan     0.1000    0.0056
     3        0.8495             nan     0.1000    0.0055
     4        0.8447             nan     0.1000    0.0048
     5        0.8402             nan     0.1000    0.0042
     6        0.8363             nan     0.1000    0.0036
     7        0.8328             nan     0.1000    0.0033
     8        0.8291             nan     0.1000    0.0035
     9        0.8258             nan     0.1000    0.0034
    10        0.8231             nan     0.1000    0.0026
    20        0.8027             nan     0.1000    0.0011
    40        0.7821             nan     0.1000    0.0008
    60        0.7708             nan     0.1000    0.0005
    80        0.7629             nan     0.1000    0.0003
   100        0.7574             nan     0.1000    0.0001

Iter   TrainDeviance   ValidDeviance   StepSize   Improve
     1        0.8583             nan     0.1000    0.0104
     2        0.8497             nan     0.1000    0.0084
     3        0.8430             nan     0.1000    0.0065
     4        0.8371             nan     0.1000    0.0056
     5        0.8315             nan     0.1000    0.0054
     6        0.8265             nan     0.1000    0.0051
     7        0.8217             nan     0.1000    0.0045
     8        0.8175             nan     0.1000    0.0040
     9        0.8137             nan     0.1000    0.0037
    10        0.8104             nan     0.1000    0.0031
    20        0.7866             nan     0.1000    0.0017
    40        0.7631             nan     0.1000    0.0005
    60        0.7512             nan     0.1000    0.0004
    80        0.7446             nan     0.1000   -0.0000
   100        0.7397             nan     0.1000   -0.0000

Iter   TrainDeviance   ValidDeviance   StepSize   Improve
     1        0.8573             nan     0.1000    0.0114
     2        0.8481             nan     0.1000    0.0090
     3        0.8397             nan     0.1000    0.0083
     4        0.8325             nan     0.1000    0.0072
     5        0.8259             nan     0.1000    0.0066
     6        0.8205             nan     0.1000    0.0054
     7        0.8152             nan     0.1000    0.0046
     8        0.8097             nan     0.1000    0.0052
     9        0.8054             nan     0.1000    0.0041
    10        0.8020             nan     0.1000    0.0030
    20        0.7750             nan     0.1000    0.0020
    40        0.7523             nan     0.1000    0.0002
    60        0.7415             nan     0.1000    0.0002
    80        0.7332             nan     0.1000    0.0002
   100        0.7263             nan     0.1000   -0.0002

Iter   TrainDeviance   ValidDeviance   StepSize   Improve
     1        0.8558             nan     0.1000    0.0125
     2        0.8455             nan     0.1000    0.0104
     3        0.8364             nan     0.1000    0.0089
     4        0.8281             nan     0.1000    0.0078
     5        0.8207             nan     0.1000    0.0069
     6        0.8149             nan     0.1000    0.0056
     7        0.8099             nan     0.1000    0.0049
     8        0.8044             nan     0.1000    0.0051
     9        0.7996             nan     0.1000    0.0049
    10        0.7961             nan     0.1000    0.0033
    20        0.7686             nan     0.1000    0.0019
    40        0.7443             nan     0.1000    0.0002
    60        0.7332             nan     0.1000    0.0001
    80        0.7240             nan     0.1000    0.0000
   100        0.7173             nan     0.1000   -0.0002

Iter   TrainDeviance   ValidDeviance   StepSize   Improve
     1        0.8551             nan     0.1000    0.0131
     2        0.8443             nan     0.1000    0.0110
     3        0.8347             nan     0.1000    0.0093
     4        0.8263             nan     0.1000    0.0085
     5        0.8186             nan     0.1000    0.0069
     6        0.8120             nan     0.1000    0.0062
     7        0.8060             nan     0.1000    0.0057
     8        0.8011             nan     0.1000    0.0045
     9        0.7955             nan     0.1000    0.0052
    10        0.7908             nan     0.1000    0.0042
    20        0.7624             nan     0.1000    0.0017
    40        0.7396             nan     0.1000    0.0000
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    60        0.7263             nan     0.1000    0.0000
    80        0.7162             nan     0.1000   -0.0001
   100        0.7077             nan     0.1000   -0.0000

Iter   TrainDeviance   ValidDeviance   StepSize   Improve
     1        0.8694             nan     0.0100    0.0007
     2        0.8687             nan     0.0100    0.0007
     3        0.8680             nan     0.0100    0.0007
     4        0.8673             nan     0.0100    0.0007
     5        0.8666             nan     0.0100    0.0007
     6        0.8659             nan     0.0100    0.0006
     7        0.8652             nan     0.0100    0.0007
     8        0.8646             nan     0.0100    0.0006
     9        0.8639             nan     0.0100    0.0006
    10        0.8633             nan     0.0100    0.0006
    20        0.8574             nan     0.0100    0.0005
    40        0.8473             nan     0.0100    0.0005
    60        0.8389             nan     0.0100    0.0004
    80        0.8316             nan     0.0100    0.0003
   100        0.8255             nan     0.0100    0.0002

Iter   TrainDeviance   ValidDeviance   StepSize   Improve
     1        0.8690             nan     0.0100    0.0011
     2        0.8680             nan     0.0100    0.0011
     3        0.8669             nan     0.0100    0.0011
     4        0.8659             nan     0.0100    0.0010
     5        0.8648             nan     0.0100    0.0010
     6        0.8638             nan     0.0100    0.0010
     7        0.8628             nan     0.0100    0.0010
     8        0.8619             nan     0.0100    0.0009
     9        0.8610             nan     0.0100    0.0009
    10        0.8601             nan     0.0100    0.0009
    20        0.8518             nan     0.0100    0.0008
    40        0.8385             nan     0.0100    0.0006
    60        0.8279             nan     0.0100    0.0004
    80        0.8190             nan     0.0100    0.0004
   100        0.8118             nan     0.0100    0.0003

Iter   TrainDeviance   ValidDeviance   StepSize   Improve
     1        0.8688             nan     0.0100    0.0012
     2        0.8677             nan     0.0100    0.0012
     3        0.8665             nan     0.0100    0.0011
     4        0.8654             nan     0.0100    0.0011
     5        0.8642             nan     0.0100    0.0011
     6        0.8631             nan     0.0100    0.0011
     7        0.8620             nan     0.0100    0.0010
     8        0.8609             nan     0.0100    0.0011
     9        0.8599             nan     0.0100    0.0010
    10        0.8588             nan     0.0100    0.0010
    20        0.8493             nan     0.0100    0.0009
    40        0.8336             nan     0.0100    0.0006
    60        0.8214             nan     0.0100    0.0005
    80        0.8113             nan     0.0100    0.0005
   100        0.8032             nan     0.0100    0.0003

Iter   TrainDeviance   ValidDeviance   StepSize   Improve
     1        0.8688             nan     0.0100    0.0013
     2        0.8674             nan     0.0100    0.0013
     3        0.8661             nan     0.0100    0.0013
     4        0.8649             nan     0.0100    0.0012
     5        0.8636             nan     0.0100    0.0013
     6        0.8624             nan     0.0100    0.0012
     7        0.8612             nan     0.0100    0.0012
     8        0.8599             nan     0.0100    0.0012
     9        0.8588             nan     0.0100    0.0011
    10        0.8577             nan     0.0100    0.0011
    20        0.8472             nan     0.0100    0.0010
    40        0.8299             nan     0.0100    0.0007
    60        0.8167             nan     0.0100    0.0005
    80        0.8059             nan     0.0100    0.0004
   100        0.7972             nan     0.0100    0.0004

Iter   TrainDeviance   ValidDeviance   StepSize   Improve
     1        0.8686             nan     0.0100    0.0014
     2        0.8672             nan     0.0100    0.0014
     3        0.8658             nan     0.0100    0.0013
     4        0.8645             nan     0.0100    0.0013
     5        0.8631             nan     0.0100    0.0013
     6        0.8617             nan     0.0100    0.0013
     7        0.8605             nan     0.0100    0.0012
     8        0.8593             nan     0.0100    0.0013
     9        0.8580             nan     0.0100    0.0012
    10        0.8568             nan     0.0100    0.0012
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    20        0.8457             nan     0.0100    0.0010
    40        0.8276             nan     0.0100    0.0008
    60        0.8134             nan     0.0100    0.0007
    80        0.8020             nan     0.0100    0.0005
   100        0.7929             nan     0.0100    0.0004

Iter   TrainDeviance   ValidDeviance   StepSize   Improve
     1        0.8630             nan     0.1000    0.0069
     2        0.8571             nan     0.1000    0.0056
     3        0.8513             nan     0.1000    0.0055
     4        0.8465             nan     0.1000    0.0045
     5        0.8421             nan     0.1000    0.0045
     6        0.8385             nan     0.1000    0.0035
     7        0.8346             nan     0.1000    0.0039
     8        0.8313             nan     0.1000    0.0032
     9        0.8278             nan     0.1000    0.0034
    10        0.8248             nan     0.1000    0.0029
    20        0.8037             nan     0.1000    0.0013
    40        0.7829             nan     0.1000    0.0007
    60        0.7712             nan     0.1000    0.0004
    80        0.7636             nan     0.1000    0.0003
   100        0.7584             nan     0.1000    0.0002

Iter   TrainDeviance   ValidDeviance   StepSize   Improve
     1        0.8601             nan     0.1000    0.0100
     2        0.8522             nan     0.1000    0.0072
     3        0.8444             nan     0.1000    0.0077
     4        0.8377             nan     0.1000    0.0064
     5        0.8319             nan     0.1000    0.0059
     6        0.8269             nan     0.1000    0.0049
     7        0.8226             nan     0.1000    0.0041
     8        0.8185             nan     0.1000    0.0040
     9        0.8147             nan     0.1000    0.0037
    10        0.8115             nan     0.1000    0.0033
    20        0.7864             nan     0.1000    0.0022
    40        0.7632             nan     0.1000    0.0006
    60        0.7525             nan     0.1000    0.0003
    80        0.7456             nan     0.1000   -0.0001
   100        0.7401             nan     0.1000    0.0001

Iter   TrainDeviance   ValidDeviance   StepSize   Improve
     1        0.8586             nan     0.1000    0.0114
     2        0.8488             nan     0.1000    0.0094
     3        0.8403             nan     0.1000    0.0081
     4        0.8332             nan     0.1000    0.0072
     5        0.8273             nan     0.1000    0.0056
     6        0.8211             nan     0.1000    0.0061
     7        0.8160             nan     0.1000    0.0049
     8        0.8112             nan     0.1000    0.0041
     9        0.8063             nan     0.1000    0.0046
    10        0.8019             nan     0.1000    0.0043
    20        0.7760             nan     0.1000    0.0016
    40        0.7531             nan     0.1000    0.0005
    60        0.7419             nan     0.1000    0.0002
    80        0.7338             nan     0.1000   -0.0001
   100        0.7277             nan     0.1000    0.0000

Iter   TrainDeviance   ValidDeviance   StepSize   Improve
     1        0.8572             nan     0.1000    0.0127
     2        0.8462             nan     0.1000    0.0107
     3        0.8366             nan     0.1000    0.0089
     4        0.8286             nan     0.1000    0.0077
     5        0.8218             nan     0.1000    0.0064
     6        0.8161             nan     0.1000    0.0054
     7        0.8101             nan     0.1000    0.0059
     8        0.8049             nan     0.1000    0.0050
     9        0.8004             nan     0.1000    0.0041
    10        0.7962             nan     0.1000    0.0038
    20        0.7689             nan     0.1000    0.0021
    40        0.7449             nan     0.1000    0.0004
    60        0.7338             nan     0.1000    0.0003
    80        0.7248             nan     0.1000    0.0000
   100        0.7175             nan     0.1000   -0.0001

Iter   TrainDeviance   ValidDeviance   StepSize   Improve
     1        0.8560             nan     0.1000    0.0133
     2        0.8444             nan     0.1000    0.0108
     3        0.8350             nan     0.1000    0.0094
     4        0.8266             nan     0.1000    0.0083
     5        0.8195             nan     0.1000    0.0068
     6        0.8120             nan     0.1000    0.0072
     7        0.8056             nan     0.1000    0.0059
     8        0.8006             nan     0.1000    0.0046
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     9        0.7959             nan     0.1000    0.0047
    10        0.7918             nan     0.1000    0.0039
    20        0.7646             nan     0.1000    0.0018
    40        0.7402             nan     0.1000    0.0002
    60        0.7280             nan     0.1000    0.0003
    80        0.7183             nan     0.1000   -0.0001
   100        0.7113             nan     0.1000   -0.0001

Iter   TrainDeviance   ValidDeviance   StepSize   Improve
     1        0.8652             nan     0.0100    0.0007
     2        0.8644             nan     0.0100    0.0007
     3        0.8637             nan     0.0100    0.0007
     4        0.8630             nan     0.0100    0.0007
     5        0.8623             nan     0.0100    0.0007
     6        0.8616             nan     0.0100    0.0007
     7        0.8610             nan     0.0100    0.0006
     8        0.8603             nan     0.0100    0.0006
     9        0.8597             nan     0.0100    0.0006
    10        0.8591             nan     0.0100    0.0006
    20        0.8532             nan     0.0100    0.0005
    40        0.8432             nan     0.0100    0.0004
    60        0.8350             nan     0.0100    0.0004
    80        0.8281             nan     0.0100    0.0003
   100        0.8221             nan     0.0100    0.0003

Iter   TrainDeviance   ValidDeviance   StepSize   Improve
     1        0.8649             nan     0.0100    0.0011
     2        0.8638             nan     0.0100    0.0011
     3        0.8628             nan     0.0100    0.0010
     4        0.8618             nan     0.0100    0.0010
     5        0.8607             nan     0.0100    0.0010
     6        0.8597             nan     0.0100    0.0010
     7        0.8588             nan     0.0100    0.0009
     8        0.8578             nan     0.0100    0.0009
     9        0.8569             nan     0.0100    0.0009
    10        0.8560             nan     0.0100    0.0009
    20        0.8479             nan     0.0100    0.0008
    40        0.8346             nan     0.0100    0.0005
    60        0.8241             nan     0.0100    0.0004
    80        0.8154             nan     0.0100    0.0004
   100        0.8083             nan     0.0100    0.0003

Iter   TrainDeviance   ValidDeviance   StepSize   Improve
     1        0.8647             nan     0.0100    0.0012
     2        0.8635             nan     0.0100    0.0011
     3        0.8624             nan     0.0100    0.0012
     4        0.8612             nan     0.0100    0.0011
     5        0.8601             nan     0.0100    0.0011
     6        0.8590             nan     0.0100    0.0011
     7        0.8579             nan     0.0100    0.0010
     8        0.8568             nan     0.0100    0.0011
     9        0.8558             nan     0.0100    0.0010
    10        0.8548             nan     0.0100    0.0010
    20        0.8454             nan     0.0100    0.0008
    40        0.8303             nan     0.0100    0.0006
    60        0.8181             nan     0.0100    0.0005
    80        0.8084             nan     0.0100    0.0004
   100        0.8002             nan     0.0100    0.0004

Iter   TrainDeviance   ValidDeviance   StepSize   Improve
     1        0.8646             nan     0.0100    0.0013
     2        0.8633             nan     0.0100    0.0013
     3        0.8621             nan     0.0100    0.0012
     4        0.8608             nan     0.0100    0.0012
     5        0.8596             nan     0.0100    0.0012
     6        0.8584             nan     0.0100    0.0012
     7        0.8573             nan     0.0100    0.0011
     8        0.8561             nan     0.0100    0.0012
     9        0.8549             nan     0.0100    0.0011
    10        0.8538             nan     0.0100    0.0011
    20        0.8435             nan     0.0100    0.0009
    40        0.8268             nan     0.0100    0.0007
    60        0.8139             nan     0.0100    0.0006
    80        0.8035             nan     0.0100    0.0004
   100        0.7946             nan     0.0100    0.0004

Iter   TrainDeviance   ValidDeviance   StepSize   Improve
     1        0.8645             nan     0.0100    0.0014
     2        0.8631             nan     0.0100    0.0013
     3        0.8618             nan     0.0100    0.0013
     4        0.8604             nan     0.0100    0.0013
     5        0.8592             nan     0.0100    0.0012
     6        0.8579             nan     0.0100    0.0012
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     7        0.8566             nan     0.0100    0.0012
     8        0.8554             nan     0.0100    0.0012
     9        0.8541             nan     0.0100    0.0012
    10        0.8530             nan     0.0100    0.0012
    20        0.8418             nan     0.0100    0.0010
    40        0.8241             nan     0.0100    0.0008
    60        0.8104             nan     0.0100    0.0006
    80        0.7993             nan     0.0100    0.0005
   100        0.7903             nan     0.0100    0.0004

Iter   TrainDeviance   ValidDeviance   StepSize   Improve
     1        0.8589             nan     0.1000    0.0071
     2        0.8532             nan     0.1000    0.0058
     3        0.8480             nan     0.1000    0.0053
     4        0.8435             nan     0.1000    0.0042
     5        0.8385             nan     0.1000    0.0047
     6        0.8345             nan     0.1000    0.0038
     7        0.8307             nan     0.1000    0.0034
     8        0.8275             nan     0.1000    0.0032
     9        0.8243             nan     0.1000    0.0031
    10        0.8214             nan     0.1000    0.0027
    20        0.8011             nan     0.1000    0.0015
    40        0.7810             nan     0.1000    0.0006
    60        0.7695             nan     0.1000    0.0004
    80        0.7620             nan     0.1000    0.0002
   100        0.7566             nan     0.1000    0.0001

Iter   TrainDeviance   ValidDeviance   StepSize   Improve
     1        0.8556             nan     0.1000    0.0104
     2        0.8474             nan     0.1000    0.0083
     3        0.8403             nan     0.1000    0.0071
     4        0.8344             nan     0.1000    0.0056
     5        0.8295             nan     0.1000    0.0045
     6        0.8238             nan     0.1000    0.0051
     7        0.8191             nan     0.1000    0.0044
     8        0.8150             nan     0.1000    0.0038
     9        0.8111             nan     0.1000    0.0037
    10        0.8077             nan     0.1000    0.0027
    20        0.7832             nan     0.1000    0.0018
    40        0.7611             nan     0.1000    0.0003
    60        0.7498             nan     0.1000    0.0003
    80        0.7432             nan     0.1000    0.0000
   100        0.7381             nan     0.1000    0.0001

Iter   TrainDeviance   ValidDeviance   StepSize   Improve
     1        0.8543             nan     0.1000    0.0117
     2        0.8449             nan     0.1000    0.0091
     3        0.8367             nan     0.1000    0.0082
     4        0.8293             nan     0.1000    0.0068
     5        0.8226             nan     0.1000    0.0062
     6        0.8172             nan     0.1000    0.0053
     7        0.8124             nan     0.1000    0.0046
     8        0.8073             nan     0.1000    0.0048
     9        0.8033             nan     0.1000    0.0038
    10        0.7993             nan     0.1000    0.0036
    20        0.7738             nan     0.1000    0.0014
    40        0.7505             nan     0.1000    0.0006
    60        0.7406             nan     0.1000    0.0001
    80        0.7325             nan     0.1000    0.0001
   100        0.7274             nan     0.1000   -0.0001

Iter   TrainDeviance   ValidDeviance   StepSize   Improve
     1        0.8532             nan     0.1000    0.0125
     2        0.8427             nan     0.1000    0.0103
     3        0.8339             nan     0.1000    0.0091
     4        0.8261             nan     0.1000    0.0077
     5        0.8196             nan     0.1000    0.0061
     6        0.8131             nan     0.1000    0.0063
     7        0.8078             nan     0.1000    0.0051
     8        0.8029             nan     0.1000    0.0041
     9        0.7976             nan     0.1000    0.0050
    10        0.7937             nan     0.1000    0.0038
    20        0.7675             nan     0.1000    0.0013
    40        0.7441             nan     0.1000    0.0002
    60        0.7319             nan     0.1000    0.0003
    80        0.7232             nan     0.1000    0.0001
   100        0.7162             nan     0.1000   -0.0002

Iter   TrainDeviance   ValidDeviance   StepSize   Improve
     1        0.8528             nan     0.1000    0.0124
     2        0.8422             nan     0.1000    0.0105
     3        0.8314             nan     0.1000    0.0097
     4        0.8233             nan     0.1000    0.0081
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     5        0.8155             nan     0.1000    0.0073
     6        0.8086             nan     0.1000    0.0061
     7        0.8029             nan     0.1000    0.0049
     8        0.7974             nan     0.1000    0.0050
     9        0.7931             nan     0.1000    0.0040
    10        0.7894             nan     0.1000    0.0033
    20        0.7616             nan     0.1000    0.0016
    40        0.7378             nan     0.1000    0.0003
    60        0.7253             nan     0.1000   -0.0000
    80        0.7158             nan     0.1000   -0.0000
   100        0.7074             nan     0.1000    0.0001

Iter   TrainDeviance   ValidDeviance   StepSize   Improve
     1        0.8655             nan     0.0100    0.0007
     2        0.8648             nan     0.0100    0.0007
     3        0.8641             nan     0.0100    0.0007
     4        0.8634             nan     0.0100    0.0007
     5        0.8627             nan     0.0100    0.0007
     6        0.8619             nan     0.0100    0.0007
     7        0.8613             nan     0.0100    0.0007
     8        0.8606             nan     0.0100    0.0006
     9        0.8600             nan     0.0100    0.0006
    10        0.8593             nan     0.0100    0.0006
    20        0.8533             nan     0.0100    0.0006
    40        0.8430             nan     0.0100    0.0005
    60        0.8346             nan     0.0100    0.0004
    80        0.8275             nan     0.0100    0.0003
   100        0.8215             nan     0.0100    0.0003

Iter   TrainDeviance   ValidDeviance   StepSize   Improve
     1        0.8652             nan     0.0100    0.0011
     2        0.8641             nan     0.0100    0.0011
     3        0.8630             nan     0.0100    0.0011
     4        0.8620             nan     0.0100    0.0010
     5        0.8610             nan     0.0100    0.0010
     6        0.8600             nan     0.0100    0.0010
     7        0.8590             nan     0.0100    0.0010
     8        0.8580             nan     0.0100    0.0010
     9        0.8570             nan     0.0100    0.0009
    10        0.8561             nan     0.0100    0.0009
    20        0.8479             nan     0.0100    0.0008
    40        0.8347             nan     0.0100    0.0005
    60        0.8241             nan     0.0100    0.0005
    80        0.8152             nan     0.0100    0.0004
   100        0.8081             nan     0.0100    0.0003

Iter   TrainDeviance   ValidDeviance   StepSize   Improve
     1        0.8651             nan     0.0100    0.0012
     2        0.8638             nan     0.0100    0.0012
     3        0.8626             nan     0.0100    0.0012
     4        0.8614             nan     0.0100    0.0012
     5        0.8603             nan     0.0100    0.0011
     6        0.8592             nan     0.0100    0.0011
     7        0.8581             nan     0.0100    0.0011
     8        0.8570             nan     0.0100    0.0011
     9        0.8560             nan     0.0100    0.0010
    10        0.8549             nan     0.0100    0.0011
    20        0.8454             nan     0.0100    0.0009
    40        0.8298             nan     0.0100    0.0006
    60        0.8177             nan     0.0100    0.0005
    80        0.8077             nan     0.0100    0.0004
   100        0.7994             nan     0.0100    0.0004

Iter   TrainDeviance   ValidDeviance   StepSize   Improve
     1        0.8649             nan     0.0100    0.0013
     2        0.8637             nan     0.0100    0.0013
     3        0.8624             nan     0.0100    0.0013
     4        0.8611             nan     0.0100    0.0012
     5        0.8598             nan     0.0100    0.0013
     6        0.8586             nan     0.0100    0.0012
     7        0.8574             nan     0.0100    0.0012
     8        0.8562             nan     0.0100    0.0012
     9        0.8550             nan     0.0100    0.0011
    10        0.8539             nan     0.0100    0.0011
    20        0.8434             nan     0.0100    0.0009
    40        0.8263             nan     0.0100    0.0007
    60        0.8131             nan     0.0100    0.0005
    80        0.8025             nan     0.0100    0.0004
   100        0.7938             nan     0.0100    0.0004

Iter   TrainDeviance   ValidDeviance   StepSize   Improve
     1        0.8648             nan     0.0100    0.0015
     2        0.8634             nan     0.0100    0.0013
```

```
     3        0.8621             nan     0.0100    0.0014
     4        0.8607             nan     0.0100    0.0013
     5        0.8594             nan     0.0100    0.0013
     6        0.8581             nan     0.0100    0.0013
     7        0.8569             nan     0.0100    0.0013
     8        0.8556             nan     0.0100    0.0012
     9        0.8544             nan     0.0100    0.0012
    10        0.8531             nan     0.0100    0.0012
    20        0.8418             nan     0.0100    0.0010
    40        0.8237             nan     0.0100    0.0008
    60        0.8098             nan     0.0100    0.0006
    80        0.7985             nan     0.0100    0.0005
   100        0.7896             nan     0.0100    0.0003

Iter   TrainDeviance   ValidDeviance   StepSize   Improve
     1        0.8590             nan     0.1000    0.0072
     2        0.8530             nan     0.1000    0.0057
     3        0.8474             nan     0.1000    0.0053
     4        0.8426             nan     0.1000    0.0048
     5        0.8384             nan     0.1000    0.0039
     6        0.8346             nan     0.1000    0.0037
     7        0.8305             nan     0.1000    0.0040
     8        0.8268             nan     0.1000    0.0033
     9        0.8234             nan     0.1000    0.0031
    10        0.8206             nan     0.1000    0.0025
    20        0.8001             nan     0.1000    0.0015
    40        0.7792             nan     0.1000    0.0005
    60        0.7679             nan     0.1000    0.0004
    80        0.7605             nan     0.1000    0.0002
   100        0.7555             nan     0.1000    0.0001

Iter   TrainDeviance   ValidDeviance   StepSize   Improve
     1        0.8558             nan     0.1000    0.0107
     2        0.8473             nan     0.1000    0.0085
     3        0.8400             nan     0.1000    0.0070
     4        0.8341             nan     0.1000    0.0058
     5        0.8284             nan     0.1000    0.0056
     6        0.8237             nan     0.1000    0.0043
     7        0.8190             nan     0.1000    0.0049
     8        0.8150             nan     0.1000    0.0037
     9        0.8113             nan     0.1000    0.0036
    10        0.8072             nan     0.1000    0.0038
    20        0.7832             nan     0.1000    0.0015
    40        0.7612             nan     0.1000    0.0006
    60        0.7499             nan     0.1000    0.0003
    80        0.7435             nan     0.1000    0.0001
   100        0.7382             nan     0.1000    0.0000

Iter   TrainDeviance   ValidDeviance   StepSize   Improve
     1        0.8544             nan     0.1000    0.0115
     2        0.8446             nan     0.1000    0.0091
     3        0.8356             nan     0.1000    0.0088
     4        0.8283             nan     0.1000    0.0071
     5        0.8222             nan     0.1000    0.0060
     6        0.8168             nan     0.1000    0.0052
     7        0.8117             nan     0.1000    0.0049
     8        0.8068             nan     0.1000    0.0041
     9        0.8028             nan     0.1000    0.0038
    10        0.7986             nan     0.1000    0.0039
    20        0.7739             nan     0.1000    0.0014
    40        0.7517             nan     0.1000    0.0004
    60        0.7402             nan     0.1000    0.0003
    80        0.7319             nan     0.1000   -0.0001
   100        0.7253             nan     0.1000    0.0003

Iter   TrainDeviance   ValidDeviance   StepSize   Improve
     1        0.8535             nan     0.1000    0.0127
     2        0.8423             nan     0.1000    0.0108
     3        0.8333             nan     0.1000    0.0085
     4        0.8252             nan     0.1000    0.0075
     5        0.8184             nan     0.1000    0.0067
     6        0.8118             nan     0.1000    0.0062
     7        0.8066             nan     0.1000    0.0049
     8        0.8009             nan     0.1000    0.0054
     9        0.7964             nan     0.1000    0.0041
    10        0.7923             nan     0.1000    0.0039
    20        0.7647             nan     0.1000    0.0017
    40        0.7415             nan     0.1000    0.0007
    60        0.7308             nan     0.1000    0.0003
    80        0.7224             nan     0.1000   -0.0000
   100        0.7158             nan     0.1000    0.0004

Iter   TrainDeviance   ValidDeviance   StepSize   Improve
```

```
     1        0.8521             nan     0.1000    0.0138
     2        0.8407             nan     0.1000    0.0113
     3        0.8311             nan     0.1000    0.0097
     4        0.8225             nan     0.1000    0.0085
     5        0.8148             nan     0.1000    0.0070
     6        0.8087             nan     0.1000    0.0063
     7        0.8033             nan     0.1000    0.0049
     8        0.7980             nan     0.1000    0.0050
     9        0.7936             nan     0.1000    0.0040
    10        0.7889             nan     0.1000    0.0040
    20        0.7602             nan     0.1000    0.0013
    40        0.7370             nan     0.1000    0.0003
    60        0.7247             nan     0.1000    0.0004
    80        0.7156             nan     0.1000   -0.0001
   100        0.7073             nan     0.1000   -0.0000

Iter   TrainDeviance   ValidDeviance   StepSize   Improve
     1        0.8672             nan     0.0100    0.0008
     2        0.8665             nan     0.0100    0.0007
     3        0.8657             nan     0.0100    0.0007
     4        0.8650             nan     0.0100    0.0007
     5        0.8643             nan     0.0100    0.0007
     6        0.8637             nan     0.0100    0.0006
     7        0.8630             nan     0.0100    0.0007
     8        0.8623             nan     0.0100    0.0007
     9        0.8616             nan     0.0100    0.0007
    10        0.8610             nan     0.0100    0.0006
    20        0.8549             nan     0.0100    0.0006
    40        0.8445             nan     0.0100    0.0005
    60        0.8360             nan     0.0100    0.0004
    80        0.8288             nan     0.0100    0.0003
   100        0.8226             nan     0.0100    0.0003

Iter   TrainDeviance   ValidDeviance   StepSize   Improve
     1        0.8670             nan     0.0100    0.0010
     2        0.8659             nan     0.0100    0.0011
     3        0.8648             nan     0.0100    0.0011
     4        0.8637             nan     0.0100    0.0010
     5        0.8627             nan     0.0100    0.0010
     6        0.8617             nan     0.0100    0.0010
     7        0.8607             nan     0.0100    0.0010
     8        0.8597             nan     0.0100    0.0010
     9        0.8588             nan     0.0100    0.0008
    10        0.8579             nan     0.0100    0.0009
    20        0.8494             nan     0.0100    0.0008
    40        0.8359             nan     0.0100    0.0005
    60        0.8253             nan     0.0100    0.0004
    80        0.8164             nan     0.0100    0.0004
   100        0.8090             nan     0.0100    0.0003

Iter   TrainDeviance   ValidDeviance   StepSize   Improve
     1        0.8667             nan     0.0100    0.0012
     2        0.8655             nan     0.0100    0.0012
     3        0.8642             nan     0.0100    0.0012
     4        0.8631             nan     0.0100    0.0012
     5        0.8619             nan     0.0100    0.0011
     6        0.8608             nan     0.0100    0.0011
     7        0.8596             nan     0.0100    0.0011
     8        0.8585             nan     0.0100    0.0011
     9        0.8574             nan     0.0100    0.0011
    10        0.8564             nan     0.0100    0.0010
    20        0.8467             nan     0.0100    0.0009
    40        0.8311             nan     0.0100    0.0007
    60        0.8187             nan     0.0100    0.0006
    80        0.8087             nan     0.0100    0.0005
   100        0.8003             nan     0.0100    0.0003

Iter   TrainDeviance   ValidDeviance   StepSize   Improve
     1        0.8667             nan     0.0100    0.0013
     2        0.8654             nan     0.0100    0.0013
     3        0.8641             nan     0.0100    0.0012
     4        0.8628             nan     0.0100    0.0013
     5        0.8615             nan     0.0100    0.0013
     6        0.8603             nan     0.0100    0.0012
     7        0.8590             nan     0.0100    0.0012
     8        0.8578             nan     0.0100    0.0012
     9        0.8567             nan     0.0100    0.0011
    10        0.8555             nan     0.0100    0.0011
    20        0.8448             nan     0.0100    0.0009
    40        0.8278             nan     0.0100    0.0007
    60        0.8144             nan     0.0100    0.0006
    80        0.8038             nan     0.0100    0.0004
   100        0.7946             nan     0.0100    0.0003
```

```
Iter   TrainDeviance   ValidDeviance   StepSize   Improve
     1        0.8665             nan     0.0100    0.0015
     2        0.8650             nan     0.0100    0.0014
     3        0.8637             nan     0.0100    0.0013
     4        0.8623             nan     0.0100    0.0013
     5        0.8609             nan     0.0100    0.0013
     6        0.8595             nan     0.0100    0.0013
     7        0.8582             nan     0.0100    0.0012
     8        0.8569             nan     0.0100    0.0012
     9        0.8557             nan     0.0100    0.0012
    10        0.8545             nan     0.0100    0.0012
    20        0.8431             nan     0.0100    0.0010
    40        0.8250             nan     0.0100    0.0008
    60        0.8109             nan     0.0100    0.0006
    80        0.7996             nan     0.0100    0.0004
   100        0.7903             nan     0.0100    0.0004

Iter   TrainDeviance   ValidDeviance   StepSize   Improve
     1        0.8607             nan     0.1000    0.0073
     2        0.8549             nan     0.1000    0.0058
     3        0.8487             nan     0.1000    0.0056
     4        0.8437             nan     0.1000    0.0047
     5        0.8393             nan     0.1000    0.0040
     6        0.8354             nan     0.1000    0.0035
     7        0.8312             nan     0.1000    0.0041
     8        0.8277             nan     0.1000    0.0033
     9        0.8243             nan     0.1000    0.0032
    10        0.8214             nan     0.1000    0.0027
    20        0.8003             nan     0.1000    0.0013
    40        0.7800             nan     0.1000    0.0006
    60        0.7684             nan     0.1000    0.0003
    80        0.7612             nan     0.1000    0.0001
   100        0.7559             nan     0.1000    0.0002

Iter   TrainDeviance   ValidDeviance   StepSize   Improve
     1        0.8587             nan     0.1000    0.0094
     2        0.8495             nan     0.1000    0.0092
     3        0.8424             nan     0.1000    0.0070
     4        0.8359             nan     0.1000    0.0064
     5        0.8302             nan     0.1000    0.0058
     6        0.8254             nan     0.1000    0.0045
     7        0.8213             nan     0.1000    0.0039
     8        0.8173             nan     0.1000    0.0038
     9        0.8125             nan     0.1000    0.0045
    10        0.8084             nan     0.1000    0.0037
    20        0.7840             nan     0.1000    0.0015
    40        0.7610             nan     0.1000    0.0006
    60        0.7498             nan     0.1000    0.0004
    80        0.7436             nan     0.1000    0.0000
   100        0.7377             nan     0.1000    0.0001

Iter   TrainDeviance   ValidDeviance   StepSize   Improve
     1        0.8563             nan     0.1000    0.0113
     2        0.8453             nan     0.1000    0.0100
     3        0.8371             nan     0.1000    0.0077
     4        0.8295             nan     0.1000    0.0073
     5        0.8234             nan     0.1000    0.0058
     6        0.8179             nan     0.1000    0.0053
     7        0.8121             nan     0.1000    0.0055
     8        0.8074             nan     0.1000    0.0048
     9        0.8034             nan     0.1000    0.0038
    10        0.7992             nan     0.1000    0.0038
    20        0.7735             nan     0.1000    0.0017
    40        0.7508             nan     0.1000    0.0008
    60        0.7403             nan     0.1000    0.0002
    80        0.7332             nan     0.1000    0.0002
   100        0.7272             nan     0.1000   -0.0000

Iter   TrainDeviance   ValidDeviance   StepSize   Improve
     1        0.8550             nan     0.1000    0.0125
     2        0.8442             nan     0.1000    0.0108
     3        0.8347             nan     0.1000    0.0089
     4        0.8262             nan     0.1000    0.0082
     5        0.8195             nan     0.1000    0.0063
     6        0.8133             nan     0.1000    0.0057
     7        0.8073             nan     0.1000    0.0058
     8        0.8023             nan     0.1000    0.0049
     9        0.7981             nan     0.1000    0.0039
    10        0.7936             nan     0.1000    0.0043
    20        0.7672             nan     0.1000    0.0016
    40        0.7436             nan     0.1000    0.0004
    60        0.7327             nan     0.1000    0.0002
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```
    80        0.7244             nan     0.1000    0.0001
   100        0.7180             nan     0.1000   -0.0001

Iter   TrainDeviance   ValidDeviance   StepSize   Improve
     1        0.8542             nan     0.1000    0.0135
     2        0.8423             nan     0.1000    0.0113
     3        0.8326             nan     0.1000    0.0092
     4        0.8246             nan     0.1000    0.0074
     5        0.8169             nan     0.1000    0.0074
     6        0.8104             nan     0.1000    0.0059
     7        0.8044             nan     0.1000    0.0059
     8        0.7993             nan     0.1000    0.0049
     9        0.7947             nan     0.1000    0.0038
    10        0.7904             nan     0.1000    0.0041
    20        0.7616             nan     0.1000    0.0018
    40        0.7371             nan     0.1000    0.0009
    60        0.7254             nan     0.1000    0.0002
    80        0.7156             nan     0.1000    0.0001
   100        0.7071             nan     0.1000   -0.0002

Iter   TrainDeviance   ValidDeviance   StepSize   Improve
     1        0.8739             nan     0.0100    0.0008
     2        0.8732             nan     0.0100    0.0007
     3        0.8724             nan     0.0100    0.0007
     4        0.8717             nan     0.0100    0.0007
     5        0.8710             nan     0.0100    0.0007
     6        0.8703             nan     0.0100    0.0007
     7        0.8696             nan     0.0100    0.0006
     8        0.8689             nan     0.0100    0.0007
     9        0.8683             nan     0.0100    0.0006
    10        0.8676             nan     0.0100    0.0006
    20        0.8616             nan     0.0100    0.0006
    40        0.8514             nan     0.0100    0.0005
    60        0.8428             nan     0.0100    0.0004
    80        0.8357             nan     0.0100    0.0003
   100        0.8296             nan     0.0100    0.0003

Iter   TrainDeviance   ValidDeviance   StepSize   Improve
     1        0.8736             nan     0.0100    0.0011
     2        0.8725             nan     0.0100    0.0011
     3        0.8715             nan     0.0100    0.0010
     4        0.8706             nan     0.0100    0.0008
     5        0.8696             nan     0.0100    0.0010
     6        0.8686             nan     0.0100    0.0010
     7        0.8676             nan     0.0100    0.0010
     8        0.8666             nan     0.0100    0.0010
     9        0.8657             nan     0.0100    0.0010
    10        0.8647             nan     0.0100    0.0009
    20        0.8563             nan     0.0100    0.0007
    40        0.8427             nan     0.0100    0.0006
    60        0.8321             nan     0.0100    0.0004
    80        0.8235             nan     0.0100    0.0004
   100        0.8163             nan     0.0100    0.0003

Iter   TrainDeviance   ValidDeviance   StepSize   Improve
     1        0.8734             nan     0.0100    0.0012
     2        0.8722             nan     0.0100    0.0012
     3        0.8710             nan     0.0100    0.0012
     4        0.8698             nan     0.0100    0.0012
     5        0.8686             nan     0.0100    0.0012
     6        0.8675             nan     0.0100    0.0011
     7        0.8664             nan     0.0100    0.0011
     8        0.8654             nan     0.0100    0.0010
     9        0.8643             nan     0.0100    0.0011
    10        0.8633             nan     0.0100    0.0010
    20        0.8538             nan     0.0100    0.0009
    40        0.8384             nan     0.0100    0.0006
    60        0.8262             nan     0.0100    0.0005
    80        0.8160             nan     0.0100    0.0005
   100        0.8078             nan     0.0100    0.0004

Iter   TrainDeviance   ValidDeviance   StepSize   Improve
     1        0.8733             nan     0.0100    0.0013
     2        0.8720             nan     0.0100    0.0013
     3        0.8707             nan     0.0100    0.0013
     4        0.8694             nan     0.0100    0.0013
     5        0.8682             nan     0.0100    0.0012
     6        0.8668             nan     0.0100    0.0012
     7        0.8657             nan     0.0100    0.0011
     8        0.8645             nan     0.0100    0.0012
     9        0.8633             nan     0.0100    0.0012
    10        0.8621             nan     0.0100    0.0012
    20        0.8516             nan     0.0100    0.0010
```

```
    40        0.8344             nan     0.0100    0.0007
    60        0.8207             nan     0.0100    0.0005
    80        0.8101             nan     0.0100    0.0004
   100        0.8013             nan     0.0100    0.0003

Iter   TrainDeviance   ValidDeviance   StepSize   Improve
     1        0.8732             nan     0.0100    0.0014
     2        0.8718             nan     0.0100    0.0014
     3        0.8704             nan     0.0100    0.0013
     4        0.8691             nan     0.0100    0.0013
     5        0.8678             nan     0.0100    0.0013
     6        0.8665             nan     0.0100    0.0012
     7        0.8651             nan     0.0100    0.0013
     8        0.8639             nan     0.0100    0.0012
     9        0.8626             nan     0.0100    0.0012
    10        0.8614             nan     0.0100    0.0012
    20        0.8500             nan     0.0100    0.0010
    40        0.8318             nan     0.0100    0.0007
    60        0.8177             nan     0.0100    0.0006
    80        0.8068             nan     0.0100    0.0005
   100        0.7976             nan     0.0100    0.0004

Iter   TrainDeviance   ValidDeviance   StepSize   Improve
     1        0.8677             nan     0.1000    0.0065
     2        0.8614             nan     0.1000    0.0062
     3        0.8556             nan     0.1000    0.0055
     4        0.8506             nan     0.1000    0.0048
     5        0.8463             nan     0.1000    0.0044
     6        0.8423             nan     0.1000    0.0037
     7        0.8387             nan     0.1000    0.0035
     8        0.8350             nan     0.1000    0.0035
     9        0.8317             nan     0.1000    0.0033
    10        0.8290             nan     0.1000    0.0028
    20        0.8087             nan     0.1000    0.0016
    40        0.7882             nan     0.1000    0.0005
    60        0.7764             nan     0.1000    0.0002
    80        0.7690             nan     0.1000    0.0003
   100        0.7636             nan     0.1000    0.0002

Iter   TrainDeviance   ValidDeviance   StepSize   Improve
     1        0.8640             nan     0.1000    0.0105
     2        0.8557             nan     0.1000    0.0080
     3        0.8483             nan     0.1000    0.0070
     4        0.8425             nan     0.1000    0.0056
     5        0.8368             nan     0.1000    0.0055
     6        0.8316             nan     0.1000    0.0052
     7        0.8270             nan     0.1000    0.0045
     8        0.8232             nan     0.1000    0.0034
     9        0.8194             nan     0.1000    0.0034
    10        0.8163             nan     0.1000    0.0030
    20        0.7928             nan     0.1000    0.0016
    40        0.7691             nan     0.1000    0.0005
    60        0.7577             nan     0.1000    0.0003
    80        0.7508             nan     0.1000   -0.0000
   100        0.7454             nan     0.1000    0.0000

Iter   TrainDeviance   ValidDeviance   StepSize   Improve
     1        0.8629             nan     0.1000    0.0117
     2        0.8526             nan     0.1000    0.0097
     3        0.8444             nan     0.1000    0.0079
     4        0.8376             nan     0.1000    0.0069
     5        0.8313             nan     0.1000    0.0059
     6        0.8261             nan     0.1000    0.0047
     7        0.8203             nan     0.1000    0.0051
     8        0.8157             nan     0.1000    0.0045
     9        0.8118             nan     0.1000    0.0035
    10        0.8083             nan     0.1000    0.0033
    20        0.7821             nan     0.1000    0.0014
    40        0.7584             nan     0.1000    0.0004
    60        0.7478             nan     0.1000    0.0003
    80        0.7406             nan     0.1000    0.0002
   100        0.7347             nan     0.1000    0.0001

Iter   TrainDeviance   ValidDeviance   StepSize   Improve
     1        0.8615             nan     0.1000    0.0128
     2        0.8505             nan     0.1000    0.0104
     3        0.8414             nan     0.1000    0.0088
     4        0.8331             nan     0.1000    0.0080
     5        0.8258             nan     0.1000    0.0067
     6        0.8200             nan     0.1000    0.0057
     7        0.8139             nan     0.1000    0.0059
     8        0.8089             nan     0.1000    0.0046
     9        0.8046             nan     0.1000    0.0041
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    10        0.8009             nan     0.1000    0.0033
    20        0.7738             nan     0.1000    0.0017
    40        0.7518             nan     0.1000    0.0003
    60        0.7398             nan     0.1000    0.0005
    80        0.7311             nan     0.1000    0.0001
   100        0.7245             nan     0.1000   -0.0000

Iter   TrainDeviance   ValidDeviance   StepSize   Improve
     1        0.8611             nan     0.1000    0.0134
     2        0.8501             nan     0.1000    0.0108
     3        0.8401             nan     0.1000    0.0097
     4        0.8318             nan     0.1000    0.0079
     5        0.8235             nan     0.1000    0.0081
     6        0.8169             nan     0.1000    0.0061
     7        0.8103             nan     0.1000    0.0062
     8        0.8053             nan     0.1000    0.0049
     9        0.8006             nan     0.1000    0.0043
    10        0.7962             nan     0.1000    0.0038
    20        0.7690             nan     0.1000    0.0013
    40        0.7461             nan     0.1000    0.0003
    60        0.7341             nan     0.1000    0.0001
    80        0.7249             nan     0.1000   -0.0000
   100        0.7170             nan     0.1000   -0.0000

Iter   TrainDeviance   ValidDeviance   StepSize   Improve
     1        0.8740             nan     0.0100    0.0008
     2        0.8733             nan     0.0100    0.0008
     3        0.8725             nan     0.0100    0.0007
     4        0.8718             nan     0.0100    0.0007
     5        0.8711             nan     0.0100    0.0007
     6        0.8704             nan     0.0100    0.0007
     7        0.8697             nan     0.0100    0.0007
     8        0.8690             nan     0.0100    0.0007
     9        0.8684             nan     0.0100    0.0007
    10        0.8677             nan     0.0100    0.0007
    20        0.8617             nan     0.0100    0.0006
    40        0.8512             nan     0.0100    0.0005
    60        0.8427             nan     0.0100    0.0004
    80        0.8355             nan     0.0100    0.0003
   100        0.8294             nan     0.0100    0.0003

Iter   TrainDeviance   ValidDeviance   StepSize   Improve
     1        0.8737             nan     0.0100    0.0011
     2        0.8726             nan     0.0100    0.0011
     3        0.8715             nan     0.0100    0.0011
     4        0.8704             nan     0.0100    0.0010
     5        0.8693             nan     0.0100    0.0010
     6        0.8684             nan     0.0100    0.0008
     7        0.8676             nan     0.0100    0.0009
     8        0.8666             nan     0.0100    0.0010
     9        0.8656             nan     0.0100    0.0010
    10        0.8647             nan     0.0100    0.0008
    20        0.8561             nan     0.0100    0.0008
    40        0.8426             nan     0.0100    0.0005
    60        0.8321             nan     0.0100    0.0004
    80        0.8235             nan     0.0100    0.0003
   100        0.8163             nan     0.0100    0.0003

Iter   TrainDeviance   ValidDeviance   StepSize   Improve
     1        0.8736             nan     0.0100    0.0013
     2        0.8723             nan     0.0100    0.0012
     3        0.8711             nan     0.0100    0.0012
     4        0.8699             nan     0.0100    0.0012
     5        0.8688             nan     0.0100    0.0011
     6        0.8677             nan     0.0100    0.0010
     7        0.8666             nan     0.0100    0.0011
     8        0.8654             nan     0.0100    0.0011
     9        0.8644             nan     0.0100    0.0011
    10        0.8633             nan     0.0100    0.0010
    20        0.8537             nan     0.0100    0.0009
    40        0.8381             nan     0.0100    0.0007
    60        0.8260             nan     0.0100    0.0005
    80        0.8158             nan     0.0100    0.0005
   100        0.8074             nan     0.0100    0.0003

Iter   TrainDeviance   ValidDeviance   StepSize   Improve
     1        0.8734             nan     0.0100    0.0013
     2        0.8720             nan     0.0100    0.0013
     3        0.8708             nan     0.0100    0.0013
     4        0.8695             nan     0.0100    0.0013
     5        0.8682             nan     0.0100    0.0013
     6        0.8670             nan     0.0100    0.0012
     7        0.8658             nan     0.0100    0.0012
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     8        0.8646             nan     0.0100    0.0012
     9        0.8633             nan     0.0100    0.0012
    10        0.8622             nan     0.0100    0.0011
    20        0.8516             nan     0.0100    0.0009
    40        0.8344             nan     0.0100    0.0007
    60        0.8211             nan     0.0100    0.0006
    80        0.8104             nan     0.0100    0.0005
   100        0.8017             nan     0.0100    0.0003

Iter   TrainDeviance   ValidDeviance   StepSize   Improve
     1        0.8734             nan     0.0100    0.0014
     2        0.8720             nan     0.0100    0.0013
     3        0.8706             nan     0.0100    0.0014
     4        0.8692             nan     0.0100    0.0014
     5        0.8679             nan     0.0100    0.0013
     6        0.8666             nan     0.0100    0.0013
     7        0.8653             nan     0.0100    0.0012
     8        0.8640             nan     0.0100    0.0013
     9        0.8627             nan     0.0100    0.0013
    10        0.8615             nan     0.0100    0.0012
    20        0.8500             nan     0.0100    0.0010
    40        0.8316             nan     0.0100    0.0008
    60        0.8177             nan     0.0100    0.0006
    80        0.8063             nan     0.0100    0.0004
   100        0.7973             nan     0.0100    0.0004

Iter   TrainDeviance   ValidDeviance   StepSize   Improve
     1        0.8674             nan     0.1000    0.0073
     2        0.8614             nan     0.1000    0.0059
     3        0.8557             nan     0.1000    0.0056
     4        0.8508             nan     0.1000    0.0051
     5        0.8465             nan     0.1000    0.0041
     6        0.8423             nan     0.1000    0.0042
     7        0.8386             nan     0.1000    0.0037
     8        0.8351             nan     0.1000    0.0033
     9        0.8318             nan     0.1000    0.0032
    10        0.8289             nan     0.1000    0.0026
    20        0.8085             nan     0.1000    0.0013
    40        0.7879             nan     0.1000    0.0006
    60        0.7763             nan     0.1000    0.0004
    80        0.7689             nan     0.1000    0.0003
   100        0.7635             nan     0.1000    0.0001

Iter   TrainDeviance   ValidDeviance   StepSize   Improve
     1        0.8643             nan     0.1000    0.0106
     2        0.8555             nan     0.1000    0.0088
     3        0.8481             nan     0.1000    0.0069
     4        0.8419             nan     0.1000    0.0063
     5        0.8362             nan     0.1000    0.0054
     6        0.8309             nan     0.1000    0.0052
     7        0.8265             nan     0.1000    0.0043
     8        0.8226             nan     0.1000    0.0035
     9        0.8187             nan     0.1000    0.0037
    10        0.8153             nan     0.1000    0.0033
    20        0.7912             nan     0.1000    0.0016
    40        0.7683             nan     0.1000    0.0006
    60        0.7573             nan     0.1000    0.0001
    80        0.7502             nan     0.1000    0.0002
   100        0.7450             nan     0.1000   -0.0000

Iter   TrainDeviance   ValidDeviance   StepSize   Improve
     1        0.8632             nan     0.1000    0.0115
     2        0.8530             nan     0.1000    0.0101
     3        0.8449             nan     0.1000    0.0076
     4        0.8371             nan     0.1000    0.0072
     5        0.8307             nan     0.1000    0.0064
     6        0.8248             nan     0.1000    0.0056
     7        0.8186             nan     0.1000    0.0057
     8        0.8137             nan     0.1000    0.0043
     9        0.8090             nan     0.1000    0.0045
    10        0.8053             nan     0.1000    0.0034
    20        0.7797             nan     0.1000    0.0020
    40        0.7572             nan     0.1000    0.0002
    60        0.7460             nan     0.1000    0.0001
    80        0.7392             nan     0.1000   -0.0000
   100        0.7328             nan     0.1000   -0.0000

Iter   TrainDeviance   ValidDeviance   StepSize   Improve
     1        0.8618             nan     0.1000    0.0125
     2        0.8506             nan     0.1000    0.0109
     3        0.8417             nan     0.1000    0.0089
     4        0.8341             nan     0.1000    0.0073
     5        0.8266             nan     0.1000    0.0073
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     6        0.8205             nan     0.1000    0.0060
     7        0.8146             nan     0.1000    0.0055
     8        0.8091             nan     0.1000    0.0057
     9        0.8044             nan     0.1000    0.0045
    10        0.8004             nan     0.1000    0.0036
    20        0.7738             nan     0.1000    0.0013
    40        0.7513             nan     0.1000    0.0002
    60        0.7393             nan     0.1000    0.0005
    80        0.7313             nan     0.1000    0.0001
   100        0.7239             nan     0.1000    0.0005

Iter   TrainDeviance   ValidDeviance   StepSize   Improve
     1        0.8609             nan     0.1000    0.0136
     2        0.8492             nan     0.1000    0.0110
     3        0.8390             nan     0.1000    0.0092
     4        0.8309             nan     0.1000    0.0077
     5        0.8238             nan     0.1000    0.0070
     6        0.8173             nan     0.1000    0.0057
     7        0.8107             nan     0.1000    0.0061
     8        0.8057             nan     0.1000    0.0048
     9        0.8012             nan     0.1000    0.0040
    10        0.7971             nan     0.1000    0.0035
    20        0.7679             nan     0.1000    0.0015
    40        0.7441             nan     0.1000    0.0002
    60        0.7319             nan     0.1000    0.0003
    80        0.7216             nan     0.1000   -0.0001
   100        0.7134             nan     0.1000   -0.0002

Iter   TrainDeviance   ValidDeviance   StepSize   Improve
     1        0.8715             nan     0.0100    0.0007
     2        0.8708             nan     0.0100    0.0007
     3        0.8701             nan     0.0100    0.0007
     4        0.8694             nan     0.0100    0.0007
     5        0.8687             nan     0.0100    0.0006
     6        0.8681             nan     0.0100    0.0007
     7        0.8674             nan     0.0100    0.0007
     8        0.8668             nan     0.0100    0.0006
     9        0.8661             nan     0.0100    0.0006
    10        0.8655             nan     0.0100    0.0006
    20        0.8597             nan     0.0100    0.0005
    40        0.8496             nan     0.0100    0.0004
    60        0.8412             nan     0.0100    0.0004
    80        0.8342             nan     0.0100    0.0003
   100        0.8282             nan     0.0100    0.0003

Iter   TrainDeviance   ValidDeviance   StepSize   Improve
     1        0.8711             nan     0.0100    0.0011
     2        0.8701             nan     0.0100    0.0010
     3        0.8691             nan     0.0100    0.0010
     4        0.8680             nan     0.0100    0.0010
     5        0.8671             nan     0.0100    0.0010
     6        0.8662             nan     0.0100    0.0009
     7        0.8652             nan     0.0100    0.0010
     8        0.8643             nan     0.0100    0.0009
     9        0.8635             nan     0.0100    0.0008
    10        0.8625             nan     0.0100    0.0009
    20        0.8542             nan     0.0100    0.0007
    40        0.8410             nan     0.0100    0.0006
    60        0.8308             nan     0.0100    0.0004
    80        0.8222             nan     0.0100    0.0004
   100        0.8151             nan     0.0100    0.0003

Iter   TrainDeviance   ValidDeviance   StepSize   Improve
     1        0.8710             nan     0.0100    0.0012
     2        0.8698             nan     0.0100    0.0012
     3        0.8687             nan     0.0100    0.0012
     4        0.8675             nan     0.0100    0.0011
     5        0.8664             nan     0.0100    0.0011
     6        0.8653             nan     0.0100    0.0010
     7        0.8642             nan     0.0100    0.0011
     8        0.8631             nan     0.0100    0.0011
     9        0.8620             nan     0.0100    0.0010
    10        0.8610             nan     0.0100    0.0010
    20        0.8516             nan     0.0100    0.0008
    40        0.8364             nan     0.0100    0.0006
    60        0.8242             nan     0.0100    0.0005
    80        0.8143             nan     0.0100    0.0004
   100        0.8064             nan     0.0100    0.0004

Iter   TrainDeviance   ValidDeviance   StepSize   Improve
     1        0.8709             nan     0.0100    0.0013
     2        0.8696             nan     0.0100    0.0013
     3        0.8683             nan     0.0100    0.0013
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     4        0.8671             nan     0.0100    0.0012
     5        0.8658             nan     0.0100    0.0011
     6        0.8646             nan     0.0100    0.0012
     7        0.8634             nan     0.0100    0.0012
     8        0.8623             nan     0.0100    0.0012
     9        0.8612             nan     0.0100    0.0011
    10        0.8600             nan     0.0100    0.0011
    20        0.8496             nan     0.0100    0.0009
    40        0.8330             nan     0.0100    0.0007
    60        0.8199             nan     0.0100    0.0006
    80        0.8093             nan     0.0100    0.0004
   100        0.8006             nan     0.0100    0.0004

Iter   TrainDeviance   ValidDeviance   StepSize   Improve
     1        0.8708             nan     0.0100    0.0014
     2        0.8694             nan     0.0100    0.0013
     3        0.8681             nan     0.0100    0.0013
     4        0.8668             nan     0.0100    0.0013
     5        0.8654             nan     0.0100    0.0013
     6        0.8641             nan     0.0100    0.0013
     7        0.8627             nan     0.0100    0.0013
     8        0.8615             nan     0.0100    0.0012
     9        0.8602             nan     0.0100    0.0012
    10        0.8590             nan     0.0100    0.0011
    20        0.8479             nan     0.0100    0.0011
    40        0.8299             nan     0.0100    0.0007
    60        0.8162             nan     0.0100    0.0005
    80        0.8051             nan     0.0100    0.0005
   100        0.7962             nan     0.0100    0.0004

Iter   TrainDeviance   ValidDeviance   StepSize   Improve
     1        0.8653             nan     0.1000    0.0069
     2        0.8595             nan     0.1000    0.0059
     3        0.8539             nan     0.1000    0.0053
     4        0.8489             nan     0.1000    0.0049
     5        0.8448             nan     0.1000    0.0039
     6        0.8409             nan     0.1000    0.0040
     7        0.8371             nan     0.1000    0.0037
     8        0.8337             nan     0.1000    0.0031
     9        0.8306             nan     0.1000    0.0030
    10        0.8279             nan     0.1000    0.0024
    20        0.8074             nan     0.1000    0.0012
    40        0.7866             nan     0.1000    0.0006
    60        0.7750             nan     0.1000    0.0003
    80        0.7673             nan     0.1000    0.0003
   100        0.7621             nan     0.1000    0.0001

Iter   TrainDeviance   ValidDeviance   StepSize   Improve
     1        0.8621             nan     0.1000    0.0102
     2        0.8541             nan     0.1000    0.0078
     3        0.8465             nan     0.1000    0.0075
     4        0.8403             nan     0.1000    0.0061
     5        0.8348             nan     0.1000    0.0051
     6        0.8297             nan     0.1000    0.0049
     7        0.8250             nan     0.1000    0.0045
     8        0.8209             nan     0.1000    0.0036
     9        0.8172             nan     0.1000    0.0036
    10        0.8139             nan     0.1000    0.0030
    20        0.7894             nan     0.1000    0.0018
    40        0.7675             nan     0.1000    0.0006
    60        0.7558             nan     0.1000    0.0006
    80        0.7494             nan     0.1000    0.0002
   100        0.7443             nan     0.1000    0.0001

Iter   TrainDeviance   ValidDeviance   StepSize   Improve
     1        0.8603             nan     0.1000    0.0114
     2        0.8506             nan     0.1000    0.0095
     3        0.8427             nan     0.1000    0.0078
     4        0.8358             nan     0.1000    0.0067
     5        0.8291             nan     0.1000    0.0061
     6        0.8237             nan     0.1000    0.0049
     7        0.8186             nan     0.1000    0.0049
     8        0.8133             nan     0.1000    0.0051
     9        0.8096             nan     0.1000    0.0035
    10        0.8055             nan     0.1000    0.0037
    20        0.7785             nan     0.1000    0.0019
    40        0.7571             nan     0.1000    0.0006
    60        0.7458             nan     0.1000    0.0003
    80        0.7382             nan     0.1000    0.0001
   100        0.7322             nan     0.1000   -0.0001

Iter   TrainDeviance   ValidDeviance   StepSize   Improve
     1        0.8596             nan     0.1000    0.0124
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     2        0.8495             nan     0.1000    0.0102
     3        0.8400             nan     0.1000    0.0091
     4        0.8319             nan     0.1000    0.0075
     5        0.8250             nan     0.1000    0.0063
     6        0.8187             nan     0.1000    0.0059
     7        0.8128             nan     0.1000    0.0058
     8        0.8080             nan     0.1000    0.0045
     9        0.8035             nan     0.1000    0.0042
    10        0.7990             nan     0.1000    0.0040
    20        0.7722             nan     0.1000    0.0021
    40        0.7496             nan     0.1000    0.0005
    60        0.7369             nan     0.1000    0.0002
    80        0.7289             nan     0.1000    0.0001
   100        0.7217             nan     0.1000    0.0000

Iter   TrainDeviance   ValidDeviance   StepSize   Improve
     1        0.8585             nan     0.1000    0.0131
     2        0.8470             nan     0.1000    0.0111
     3        0.8368             nan     0.1000    0.0094
     4        0.8289             nan     0.1000    0.0076
     5        0.8214             nan     0.1000    0.0072
     6        0.8153             nan     0.1000    0.0057
     7        0.8102             nan     0.1000    0.0046
     8        0.8047             nan     0.1000    0.0051
     9        0.8006             nan     0.1000    0.0042
    10        0.7965             nan     0.1000    0.0039
    20        0.7677             nan     0.1000    0.0019
    40        0.7433             nan     0.1000    0.0006
    60        0.7315             nan     0.1000    0.0002
    80        0.7218             nan     0.1000    0.0001
   100        0.7139             nan     0.1000   -0.0000

Iter   TrainDeviance   ValidDeviance   StepSize   Improve
     1        0.8674             nan     0.0100    0.0007
     2        0.8666             nan     0.0100    0.0007
     3        0.8659             nan     0.0100    0.0007
     4        0.8652             nan     0.0100    0.0007
     5        0.8645             nan     0.0100    0.0007
     6        0.8638             nan     0.0100    0.0007
     7        0.8632             nan     0.0100    0.0007
     8        0.8625             nan     0.0100    0.0007
     9        0.8619             nan     0.0100    0.0006
    10        0.8612             nan     0.0100    0.0006
    20        0.8554             nan     0.0100    0.0005
    40        0.8455             nan     0.0100    0.0004
    60        0.8373             nan     0.0100    0.0004
    80        0.8304             nan     0.0100    0.0003
   100        0.8245             nan     0.0100    0.0003

Iter   TrainDeviance   ValidDeviance   StepSize   Improve
     1        0.8670             nan     0.0100    0.0011
     2        0.8659             nan     0.0100    0.0011
     3        0.8648             nan     0.0100    0.0010
     4        0.8638             nan     0.0100    0.0010
     5        0.8628             nan     0.0100    0.0010
     6        0.8619             nan     0.0100    0.0009
     7        0.8609             nan     0.0100    0.0009
     8        0.8599             nan     0.0100    0.0010
     9        0.8590             nan     0.0100    0.0009
    10        0.8581             nan     0.0100    0.0009
    20        0.8499             nan     0.0100    0.0008
    40        0.8368             nan     0.0100    0.0006
    60        0.8265             nan     0.0100    0.0005
    80        0.8180             nan     0.0100    0.0004
   100        0.8109             nan     0.0100    0.0003

Iter   TrainDeviance   ValidDeviance   StepSize   Improve
     1        0.8669             nan     0.0100    0.0012
     2        0.8658             nan     0.0100    0.0012
     3        0.8646             nan     0.0100    0.0011
     4        0.8635             nan     0.0100    0.0011
     5        0.8624             nan     0.0100    0.0011
     6        0.8613             nan     0.0100    0.0011
     7        0.8602             nan     0.0100    0.0011
     8        0.8590             nan     0.0100    0.0011
     9        0.8580             nan     0.0100    0.0010
    10        0.8570             nan     0.0100    0.0010
    20        0.8476             nan     0.0100    0.0009
    40        0.8324             nan     0.0100    0.0006
    60        0.8207             nan     0.0100    0.0005
    80        0.8108             nan     0.0100    0.0004
   100        0.8027             nan     0.0100    0.0003
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Iter   TrainDeviance   ValidDeviance   StepSize   Improve
     1        0.8669             nan     0.0100    0.0012
     2        0.8656             nan     0.0100    0.0012
     3        0.8644             nan     0.0100    0.0012
     4        0.8632             nan     0.0100    0.0012
     5        0.8620             nan     0.0100    0.0012
     6        0.8607             nan     0.0100    0.0012
     7        0.8595             nan     0.0100    0.0012
     8        0.8583             nan     0.0100    0.0011
     9        0.8571             nan     0.0100    0.0011
    10        0.8560             nan     0.0100    0.0011
    20        0.8457             nan     0.0100    0.0009
    40        0.8291             nan     0.0100    0.0007
    60        0.8160             nan     0.0100    0.0006
    80        0.8057             nan     0.0100    0.0004
   100        0.7971             nan     0.0100    0.0003

Iter   TrainDeviance   ValidDeviance   StepSize   Improve
     1        0.8667             nan     0.0100    0.0014
     2        0.8654             nan     0.0100    0.0013
     3        0.8640             nan     0.0100    0.0014
     4        0.8626             nan     0.0100    0.0013
     5        0.8613             nan     0.0100    0.0013
     6        0.8601             nan     0.0100    0.0012
     7        0.8588             nan     0.0100    0.0012
     8        0.8575             nan     0.0100    0.0012
     9        0.8564             nan     0.0100    0.0012
    10        0.8551             nan     0.0100    0.0012
    20        0.8442             nan     0.0100    0.0010
    40        0.8264             nan     0.0100    0.0007
    60        0.8127             nan     0.0100    0.0006
    80        0.8017             nan     0.0100    0.0004
   100        0.7927             nan     0.0100    0.0004

Iter   TrainDeviance   ValidDeviance   StepSize   Improve
     1        0.8612             nan     0.1000    0.0072
     2        0.8554             nan     0.1000    0.0057
     3        0.8498             nan     0.1000    0.0053
     4        0.8450             nan     0.1000    0.0047
     5        0.8407             nan     0.1000    0.0042
     6        0.8366             nan     0.1000    0.0039
     7        0.8332             nan     0.1000    0.0031
     8        0.8297             nan     0.1000    0.0032
     9        0.8267             nan     0.1000    0.0031
    10        0.8237             nan     0.1000    0.0029
    20        0.8036             nan     0.1000    0.0014
    40        0.7831             nan     0.1000    0.0007
    60        0.7717             nan     0.1000    0.0003
    80        0.7641             nan     0.1000    0.0002
   100        0.7590             nan     0.1000    0.0001

Iter   TrainDeviance   ValidDeviance   StepSize   Improve
     1        0.8576             nan     0.1000    0.0101
     2        0.8491             nan     0.1000    0.0084
     3        0.8422             nan     0.1000    0.0068
     4        0.8364             nan     0.1000    0.0058
     5        0.8314             nan     0.1000    0.0047
     6        0.8268             nan     0.1000    0.0043
     7        0.8225             nan     0.1000    0.0039
     8        0.8179             nan     0.1000    0.0043
     9        0.8144             nan     0.1000    0.0034
    10        0.8109             nan     0.1000    0.0033
    20        0.7874             nan     0.1000    0.0015
    40        0.7643             nan     0.1000    0.0007
    60        0.7540             nan     0.1000    0.0002
    80        0.7470             nan     0.1000    0.0000
   100        0.7413             nan     0.1000    0.0001

Iter   TrainDeviance   ValidDeviance   StepSize   Improve
     1        0.8565             nan     0.1000    0.0112
     2        0.8470             nan     0.1000    0.0094
     3        0.8391             nan     0.1000    0.0076
     4        0.8323             nan     0.1000    0.0064
     5        0.8258             nan     0.1000    0.0061
     6        0.8207             nan     0.1000    0.0049
     7        0.8155             nan     0.1000    0.0049
     8        0.8106             nan     0.1000    0.0046
     9        0.8061             nan     0.1000    0.0040
    10        0.8020             nan     0.1000    0.0039
    20        0.7763             nan     0.1000    0.0018
    40        0.7540             nan     0.1000    0.0005
    60        0.7429             nan     0.1000   -0.0000
    80        0.7357             nan     0.1000   -0.0000
```

```
   100        0.7297             nan     0.1000   -0.0000

Iter   TrainDeviance   ValidDeviance   StepSize   Improve
     1        0.8556             nan     0.1000    0.0124
     2        0.8450             nan     0.1000    0.0101
     3        0.8361             nan     0.1000    0.0083
     4        0.8280             nan     0.1000    0.0079
     5        0.8215             nan     0.1000    0.0062
     6        0.8149             nan     0.1000    0.0066
     7        0.8089             nan     0.1000    0.0052
     8        0.8041             nan     0.1000    0.0044
     9        0.7997             nan     0.1000    0.0040
    10        0.7955             nan     0.1000    0.0040
    20        0.7698             nan     0.1000    0.0015
    40        0.7451             nan     0.1000    0.0008
    60        0.7334             nan     0.1000    0.0001
    80        0.7257             nan     0.1000    0.0000
   100        0.7190             nan     0.1000   -0.0001

Iter   TrainDeviance   ValidDeviance   StepSize   Improve
     1        0.8549             nan     0.1000    0.0130
     2        0.8433             nan     0.1000    0.0108
     3        0.8337             nan     0.1000    0.0095
     4        0.8254             nan     0.1000    0.0077
     5        0.8182             nan     0.1000    0.0067
     6        0.8123             nan     0.1000    0.0060
     7        0.8065             nan     0.1000    0.0050
     8        0.8009             nan     0.1000    0.0057
     9        0.7958             nan     0.1000    0.0046
    10        0.7916             nan     0.1000    0.0040
    20        0.7641             nan     0.1000    0.0017
    40        0.7399             nan     0.1000    0.0003
    60        0.7277             nan     0.1000    0.0002
    80        0.7187             nan     0.1000   -0.0000
   100        0.7104             nan     0.1000    0.0001

Iter   TrainDeviance   ValidDeviance   StepSize   Improve
     1        0.8630             nan     0.0100    0.0008
     2        0.8622             nan     0.0100    0.0007
     3        0.8615             nan     0.0100    0.0007
     4        0.8608             nan     0.0100    0.0007
     5        0.8601             nan     0.0100    0.0007
     6        0.8594             nan     0.0100    0.0007
     7        0.8588             nan     0.0100    0.0006
     8        0.8581             nan     0.0100    0.0007
     9        0.8574             nan     0.0100    0.0006
    10        0.8568             nan     0.0100    0.0006
    20        0.8509             nan     0.0100    0.0005
    40        0.8407             nan     0.0100    0.0004
    60        0.8324             nan     0.0100    0.0004
    80        0.8254             nan     0.0100    0.0003
   100        0.8193             nan     0.0100    0.0003

Iter   TrainDeviance   ValidDeviance   StepSize   Improve
     1        0.8626             nan     0.0100    0.0011
     2        0.8615             nan     0.0100    0.0011
     3        0.8605             nan     0.0100    0.0011
     4        0.8595             nan     0.0100    0.0010
     5        0.8585             nan     0.0100    0.0010
     6        0.8576             nan     0.0100    0.0008
     7        0.8566             nan     0.0100    0.0010
     8        0.8556             nan     0.0100    0.0010
     9        0.8547             nan     0.0100    0.0009
    10        0.8538             nan     0.0100    0.0009
    20        0.8455             nan     0.0100    0.0007
    40        0.8321             nan     0.0100    0.0005
    60        0.8216             nan     0.0100    0.0004
    80        0.8133             nan     0.0100    0.0004
   100        0.8061             nan     0.0100    0.0003

Iter   TrainDeviance   ValidDeviance   StepSize   Improve
     1        0.8625             nan     0.0100    0.0012
     2        0.8613             nan     0.0100    0.0012
     3        0.8601             nan     0.0100    0.0012
     4        0.8589             nan     0.0100    0.0012
     5        0.8577             nan     0.0100    0.0012
     6        0.8566             nan     0.0100    0.0011
     7        0.8555             nan     0.0100    0.0011
     8        0.8544             nan     0.0100    0.0010
     9        0.8534             nan     0.0100    0.0010
    10        0.8523             nan     0.0100    0.0010
    20        0.8427             nan     0.0100    0.0008
    40        0.8276             nan     0.0100    0.0006
```

```
    60        0.8155             nan     0.0100    0.0005
    80        0.8057             nan     0.0100    0.0004
   100        0.7974             nan     0.0100    0.0004

Iter   TrainDeviance   ValidDeviance   StepSize   Improve
     1        0.8624             nan     0.0100    0.0013
     2        0.8610             nan     0.0100    0.0013
     3        0.8597             nan     0.0100    0.0013
     4        0.8584             nan     0.0100    0.0013
     5        0.8571             nan     0.0100    0.0012
     6        0.8559             nan     0.0100    0.0012
     7        0.8547             nan     0.0100    0.0012
     8        0.8535             nan     0.0100    0.0012
     9        0.8524             nan     0.0100    0.0011
    10        0.8513             nan     0.0100    0.0011
    20        0.8409             nan     0.0100    0.0009
    40        0.8241             nan     0.0100    0.0007
    60        0.8110             nan     0.0100    0.0006
    80        0.8006             nan     0.0100    0.0004
   100        0.7919             nan     0.0100    0.0003

Iter   TrainDeviance   ValidDeviance   StepSize   Improve
     1        0.8623             nan     0.0100    0.0014
     2        0.8609             nan     0.0100    0.0013
     3        0.8595             nan     0.0100    0.0013
     4        0.8582             nan     0.0100    0.0013
     5        0.8569             nan     0.0100    0.0013
     6        0.8556             nan     0.0100    0.0013
     7        0.8543             nan     0.0100    0.0013
     8        0.8531             nan     0.0100    0.0012
     9        0.8518             nan     0.0100    0.0012
    10        0.8506             nan     0.0100    0.0012
    20        0.8395             nan     0.0100    0.0010
    40        0.8214             nan     0.0100    0.0008
    60        0.8076             nan     0.0100    0.0005
    80        0.7963             nan     0.0100    0.0005
   100        0.7870             nan     0.0100    0.0004

Iter   TrainDeviance   ValidDeviance   StepSize   Improve
     1        0.8566             nan     0.1000    0.0072
     2        0.8508             nan     0.1000    0.0059
     3        0.8455             nan     0.1000    0.0053
     4        0.8407             nan     0.1000    0.0046
     5        0.8364             nan     0.1000    0.0043
     6        0.8324             nan     0.1000    0.0041
     7        0.8288             nan     0.1000    0.0034
     8        0.8254             nan     0.1000    0.0032
     9        0.8224             nan     0.1000    0.0027
    10        0.8195             nan     0.1000    0.0025
    20        0.7986             nan     0.1000    0.0013
    40        0.7780             nan     0.1000    0.0007
    60        0.7665             nan     0.1000    0.0003
    80        0.7589             nan     0.1000    0.0002
   100        0.7535             nan     0.1000    0.0002

Iter   TrainDeviance   ValidDeviance   StepSize   Improve
     1        0.8534             nan     0.1000    0.0106
     2        0.8445             nan     0.1000    0.0086
     3        0.8371             nan     0.1000    0.0068
     4        0.8308             nan     0.1000    0.0060
     5        0.8256             nan     0.1000    0.0052
     6        0.8202             nan     0.1000    0.0051
     7        0.8161             nan     0.1000    0.0040
     8        0.8117             nan     0.1000    0.0039
     9        0.8082             nan     0.1000    0.0033
    10        0.8046             nan     0.1000    0.0033
    20        0.7806             nan     0.1000    0.0017
    40        0.7581             nan     0.1000    0.0007
    60        0.7473             nan     0.1000    0.0003
    80        0.7403             nan     0.1000    0.0006
   100        0.7348             nan     0.1000    0.0000

Iter   TrainDeviance   ValidDeviance   StepSize   Improve
     1        0.8524             nan     0.1000    0.0117
     2        0.8426             nan     0.1000    0.0092
     3        0.8342             nan     0.1000    0.0078
     4        0.8268             nan     0.1000    0.0070
     5        0.8207             nan     0.1000    0.0060
     6        0.8147             nan     0.1000    0.0059
     7        0.8092             nan     0.1000    0.0051
     8        0.8049             nan     0.1000    0.0041
     9        0.8007             nan     0.1000    0.0039
    10        0.7963             nan     0.1000    0.0042
```

```
    20        0.7703             nan     0.1000    0.0015
    40        0.7476             nan     0.1000    0.0004
    60        0.7364             nan     0.1000    0.0001
    80        0.7282             nan     0.1000    0.0004
   100        0.7221             nan     0.1000   -0.0002

Iter   TrainDeviance   ValidDeviance   StepSize   Improve
     1        0.8506             nan     0.1000    0.0129
     2        0.8396             nan     0.1000    0.0105
     3        0.8306             nan     0.1000    0.0085
     4        0.8225             nan     0.1000    0.0079
     5        0.8159             nan     0.1000    0.0064
     6        0.8092             nan     0.1000    0.0063
     7        0.8045             nan     0.1000    0.0047
     8        0.7997             nan     0.1000    0.0048
     9        0.7949             nan     0.1000    0.0043
    10        0.7906             nan     0.1000    0.0041
    20        0.7636             nan     0.1000    0.0015
    40        0.7400             nan     0.1000    0.0007
    60        0.7289             nan     0.1000   -0.0000
    80        0.7204             nan     0.1000   -0.0002
   100        0.7137             nan     0.1000    0.0002

Iter   TrainDeviance   ValidDeviance   StepSize   Improve
     1        0.8496             nan     0.1000    0.0135
     2        0.8375             nan     0.1000    0.0112
     3        0.8280             nan     0.1000    0.0095
     4        0.8198             nan     0.1000    0.0078
     5        0.8124             nan     0.1000    0.0071
     6        0.8062             nan     0.1000    0.0057
     7        0.8010             nan     0.1000    0.0049
     8        0.7961             nan     0.1000    0.0046
     9        0.7912             nan     0.1000    0.0043
    10        0.7862             nan     0.1000    0.0046
    20        0.7574             nan     0.1000    0.0013
    40        0.7350             nan     0.1000    0.0004
    60        0.7225             nan     0.1000    0.0001
    80        0.7129             nan     0.1000   -0.0001
   100        0.7048             nan     0.1000   -0.0001

Iter   TrainDeviance   ValidDeviance   StepSize   Improve
     1        0.8555             nan     0.1000    0.0133
     2        0.8444             nan     0.1000    0.0107
     3        0.8349             nan     0.1000    0.0095
     4        0.8261             nan     0.1000    0.0087
     5        0.8189             nan     0.1000    0.0073
     6        0.8125             nan     0.1000    0.0059
     7        0.8061             nan     0.1000    0.0063
     8        0.8013             nan     0.1000    0.0044
     9        0.7963             nan     0.1000    0.0045
    10        0.7919             nan     0.1000    0.0044
    20        0.7639             nan     0.1000    0.0018
    40        0.7398             nan     0.1000    0.0002
    60        0.7268             nan     0.1000    0.0004
    80        0.7186             nan     0.1000    0.0000
   100        0.7113             nan     0.1000    0.0001
```

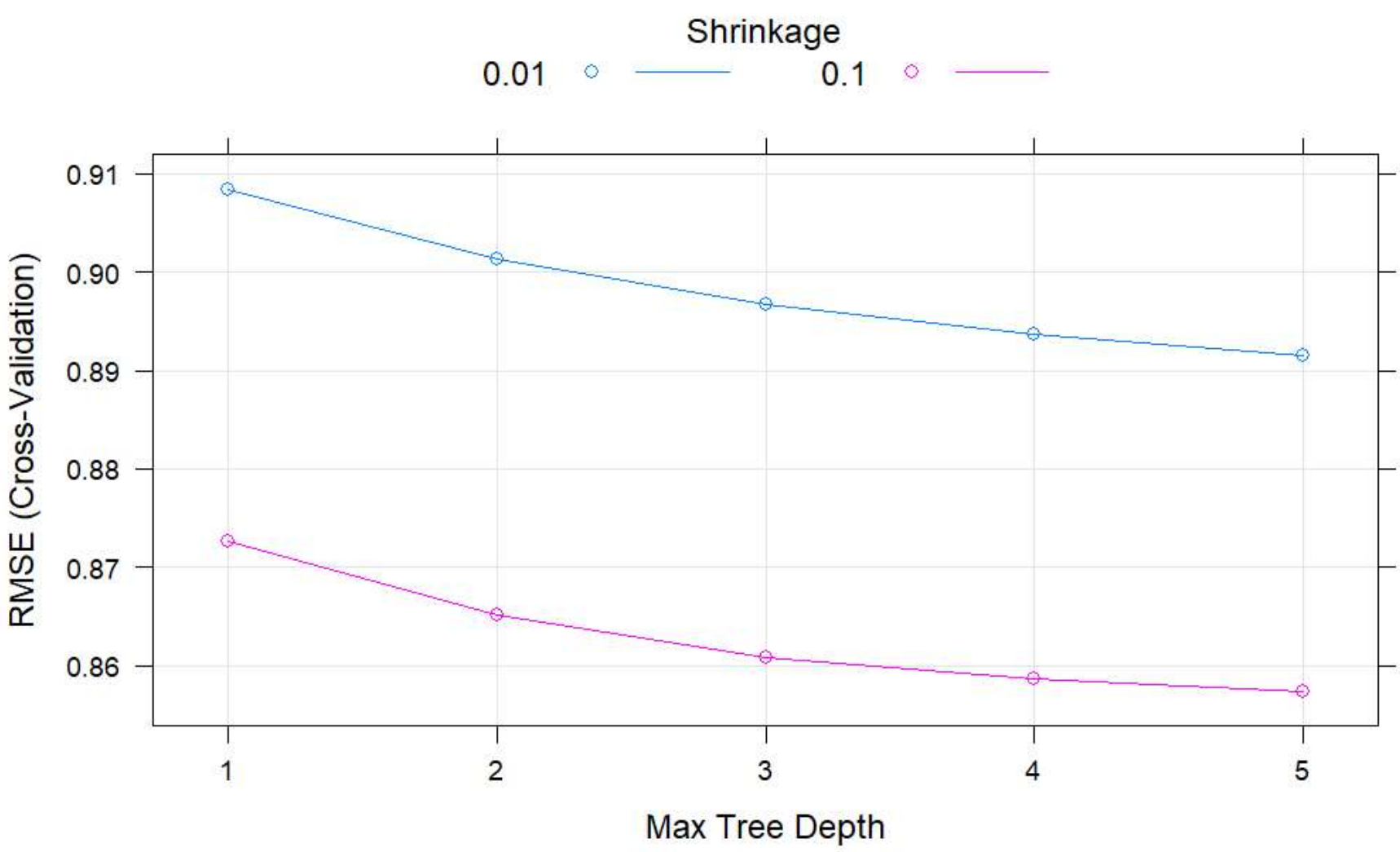
Hide

```
gbm
```

```
Stochastic Gradient Boosting

31716 samples
   44 predictor

Pre-processing: centered (44), scaled (44)
Resampling: Cross-Validated (10 fold)
Summary of sample sizes: 28545, 28543, 28544, 28545, 28545, 28543, ...
Resampling results across tuning parameters:

  shrinkage  interaction.depth  RMSE       Rsquared    MAE
  0.01       1                  0.9083963  0.08445183  0.6855248
  0.01       2                  0.9012932  0.09478318  0.6790713
  0.01       3                  0.8966554  0.10567896  0.6742977
  0.01       4                  0.8936561  0.11116160  0.6713627
  0.01       5                  0.8914927  0.11522411  0.6690840
  0.10       1                  0.8726627  0.12823473  0.6497059
  0.10       2                  0.8651327  0.14071612  0.6416147
  0.10       3                  0.8608702  0.14864414  0.6381675
  0.10       4                  0.8586408  0.15283182  0.6358339
  0.10       5                  0.8573851  0.15501048  0.6346975

Tuning parameter 'n.trees' was held constant at a value of 100
Tuning parameter 'n.minobsinnode' was held constant at a value of 10
RMSE was used to select the optimal model using the smallest value.
The final values used for the model were n.trees = 100, interaction.depth = 5, shrinkage = 0.1 and n.minobsinnode = 10.
```

Hide

```
plot(gbm)
```



Hide

```
pred.gbm <- predict(gbm, X.test)
resid.gbm <- y.test - pred.gbm
rmse(y.test, pred.gbm)
```

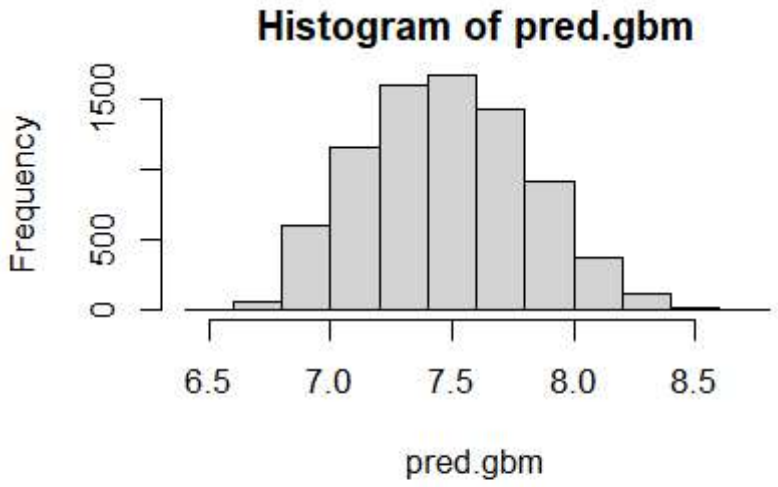
```
[1] 0.8479553
```

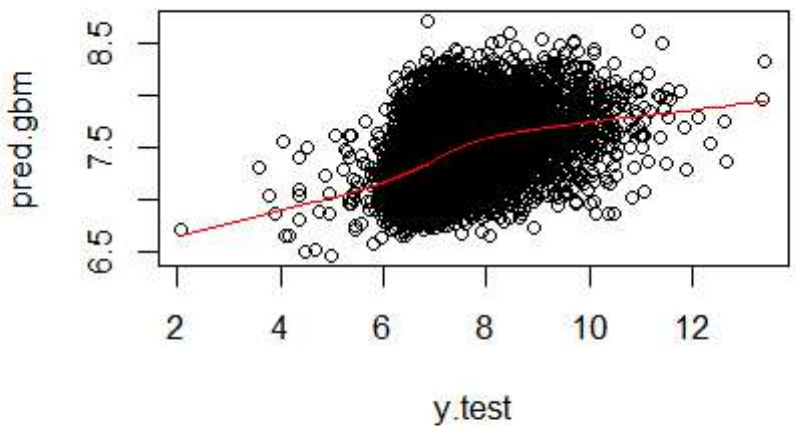
Hide

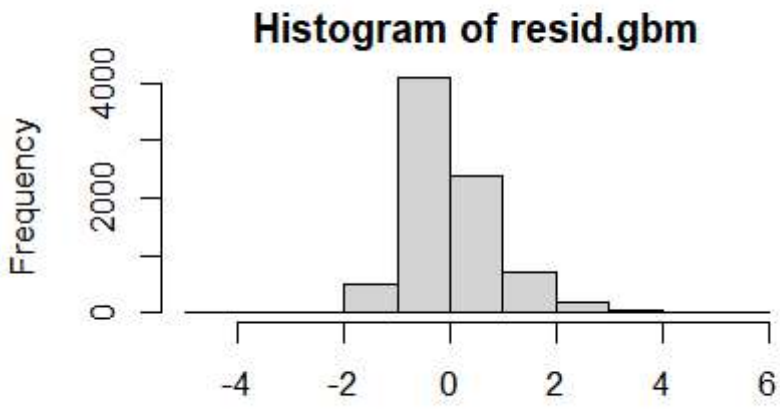
```
par(mfrow = c(2, 2))
hist(pred.gbm)
plot(y.test, pred.gbm)
```

Hide

```
lines(lowess(y.test, pred.gbm), col = "red")
hist(resid.gbm)
```







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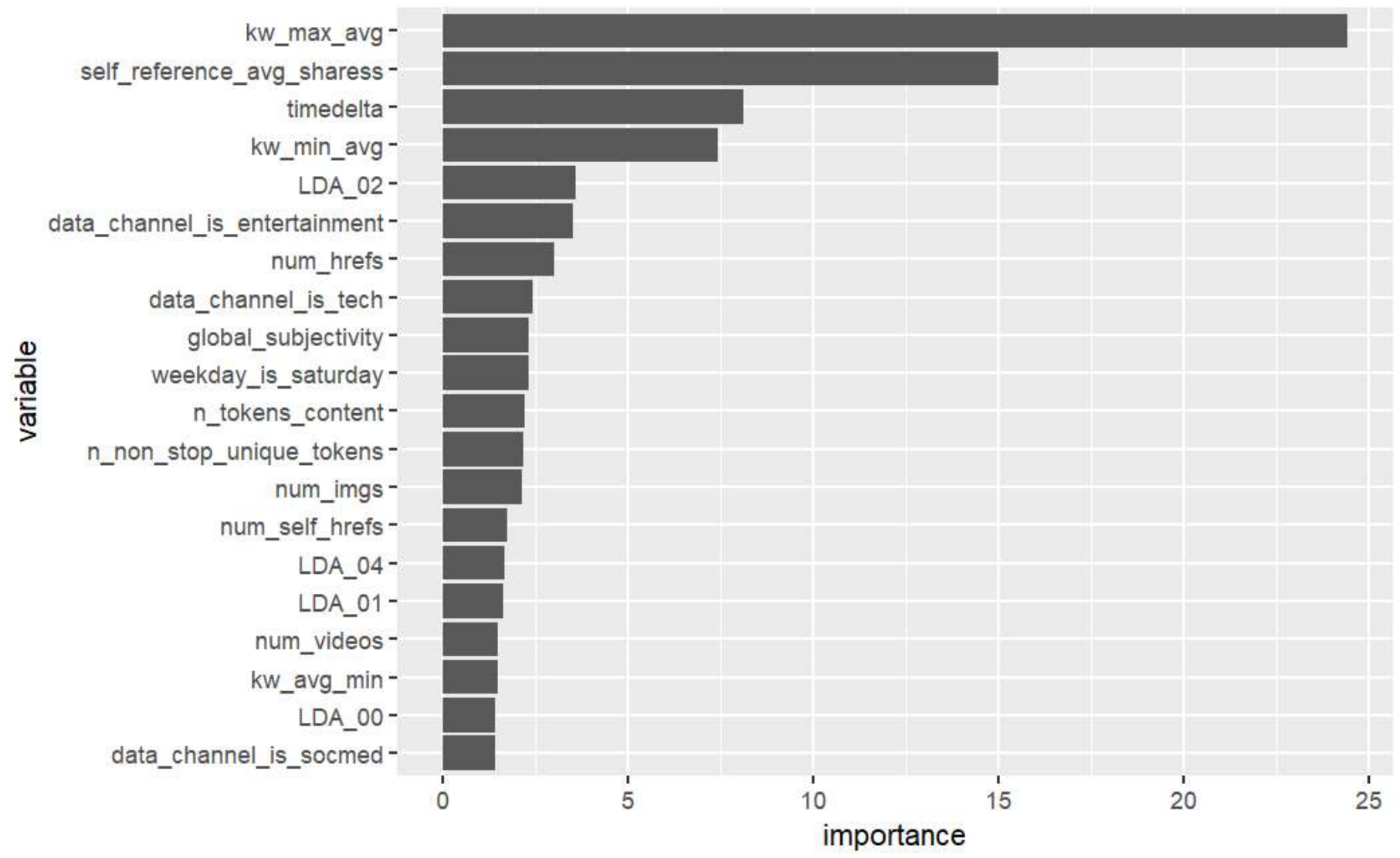
```
library(gbm)
gbm.imp <- summary.gbm(gbm$finalModel, plotit = FALSE)[1:20, ]
names(gbm.imp) <- c("variable", "importance")
gbm.imp.df <- gbm.imp %>%
  dplyr::arrange(importance) %>%
  dplyr::mutate(variable = forcats::fct_inorder(variable))
ggplot(gbm.imp.df) +
  geom_col(aes(x = variable, y = importance)) +
  coord_flip()
```



Compare Model Performance

Hide

```
# function to calculate R-squared
r.squared <- function(actual, predicted) {
  actual.mean <- mean(actual)
  RSS <- sum((actual - predicted)^2)
  TSS <- sum((actual - actual.mean)^2)
  R2 <- 1 - (RSS/TSS)
  return(R2)
}
```

Hide

```
# create dataframe to contain all model results
models <- c("enet", "pcr", "pls", "knn", "cart", "gbm")
results <- data.frame(row.names = models)
results$RMSE.cv <- NA
results$RMSE.cv.sd <- NA
results$RMSE.test <- NA
results$Rsquared.cv <- NA
results$Rsquared.cv.sd <- NA
results$Rsquared.test <- NA

# add enet results
results.enet <- enet$results %>%
  filter(lambda == enet$bestTune$lambda & fraction == enet$bestTune$fraction) %>%
  select(RMSE, RMSESD, Rsquared, RsquaredSD)

results["enet", "RMSE.cv"] <- results.enet$RMSE
results["enet", "RMSE.cv.sd"] <- results.enet$RMSESD
results["enet", "RMSE.test"] <- rmse(y.test, pred.enet)
results["enet", "Rsquared.cv"] <- results.enet$Rsquared
results["enet", "Rsquared.cv.sd"] <- results.enet$RsquaredSD
results["enet", "Rsquared.test"] <- r.squared(y.test, pred.enet)

# add PCR results
results.pcr <- pcr$results %>%
  filter(ncomp == pcr$bestTune$ncomp) %>%
  select(RMSE, RMSESD, Rsquared, RsquaredSD)

results["pcr", "RMSE.cv"] <- results.pcr$RMSE
results["pcr", "RMSE.cv.sd"] <- results.pcr$RMSESD
results["pcr", "RMSE.test"] <- rmse(y.test, pred.pcr)
results["pcr", "Rsquared.cv"] <- results.pcr$Rsquared
results["pcr", "Rsquared.cv.sd"] <- results.pcr$RsquaredSD
results["pcr", "Rsquared.test"] <- r.squared(y.test, pred.pcr)

# add PLS results
results.pls <- pls$results %>%
  filter(ncomp == pls$bestTune$ncomp) %>%
  select(RMSE, RMSESD, Rsquared, RsquaredSD)

results["pls", "RMSE.cv"] <- results.pls$RMSE
results["pls", "RMSE.cv.sd"] <- results.pls$RMSESD
results["pls", "RMSE.test"] <- rmse(y.test, pred.pls)
results["pls", "Rsquared.cv"] <- results.pls$Rsquared
results["pls", "Rsquared.cv.sd"] <- results.pls$RsquaredSD
results["pls", "Rsquared.test"] <- r.squared(y.test, pred.pls)

# add KNN results
results.knn <- knn$results %>%
  filter(k == knn$bestTune$k) %>%
  select(RMSE, RMSESD, Rsquared, RsquaredSD)

results["knn", "RMSE.cv"] <- results.knn$RMSE
results["knn", "RMSE.cv.sd"] <- results.knn$RMSESD
results["knn", "RMSE.test"] <- rmse(y.test, pred.knn)
results["knn", "Rsquared.cv"] <- results.knn$Rsquared
results["knn", "Rsquared.cv.sd"] <- results.knn$RsquaredSD
results["knn", "Rsquared.test"] <- r.squared(y.test, pred.knn)

# add CART results
results.cart <- cart$results %>%
  filter(cp == cart$bestTune$cp) %>%
  select(RMSE, RMSESD, Rsquared, RsquaredSD)

results["cart", "RMSE.cv"] <- results.cart$RMSE
results["cart", "RMSE.cv.sd"] <- results.cart$RMSESD
results["cart", "RMSE.test"] <- rmse(y.test, pred.cart)
results["cart", "Rsquared.cv"] <- results.cart$Rsquared
results["cart", "Rsquared.cv.sd"] <- results.cart$RsquaredSD
results["cart", "Rsquared.test"] <- r.squared(y.test, pred.cart)

# add GBM results
results.gbm <- gbm$results %>%
  filter(shrinkage == gbm$bestTune$shrinkage & interaction.depth == gbm$bestTune$interaction.depth) %>%
  select(RMSE, RMSESD, Rsquared, RsquaredSD)

results["gbm", "RMSE.cv"] <- results.gbm$RMSE
results["gbm", "RMSE.cv.sd"] <- results.gbm$RMSESD
results["gbm", "RMSE.test"] <- rmse(y.test, pred.gbm)
results["gbm", "Rsquared.cv"] <- results.gbm$Rsquared
results["gbm", "Rsquared.cv.sd"] <- results.gbm$RsquaredSD
results["gbm", "Rsquared.test"] <- r.squared(y.test, pred.gbm)

results
```

	RMSE.cv <dbl>	RMSE.cv.sd <dbl>	RMSE.test <dbl>	Rsquared.cv <dbl>	Rsquared.cv.sd <dbl>	Rsquared.test <dbl>
enet	0.8864478	0.021979139	0.8736786	0.09719415	0.016801650	0.10398836
pcr	0.9506298	0.084007318	0.9152851	0.01371925	0.006115983	0.01661621
pls	0.9061434	0.074589273	0.8735161	0.09218942	0.028958196	0.10432158
knn	0.9062993	0.019273590	0.9015301	0.08204549	0.009945894	0.04595076
cart	0.8924639	0.007097887	0.8773104	0.08998393	0.006609173	0.09652342
gbm	0.8573851	0.017649409	0.8479553	0.15501048	0.010350722	0.15597315

6 rows