Text Analytics 1

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Problem Description: **SEPARATING SPAM FROM HAM**

Nearly every email user has at some point encountered a "spam" email, which is an unsolicited message often advertising a product, containing links to malware, or attempting to scam the recipient. Roughly 80-90% of more than 100 billion emails sent each day are spam emails, most being sent from botnets of malware-infected computers. The remainder of emails are called "ham" emails.

As a result of the huge number of spam emails being sent across the Internet each day, most email providers offer a spam filter that automatically flags likely spam messages and separates them from the ham. Though these filters use a number of techniques (e.g. looking up the sender in a so-called "Blackhole List" that contains IP addresses of likely spammers), most rely heavily on the analysis of the contents of an email via text analytics.

We will build and evaluate a spam filter using a publicly available dataset first described in the 2006 conference paper "Spam Filtering with Naive Bayes – Which Naive Bayes?" by V. Metsis, I. Androutsopoulos, and G. Paliouras. The "ham" messages in this dataset come from the inbox of former Enron Managing Director for Research Vincent Kaminski, one of the inboxes in the Enron Corpus. One source of spam messages in this dataset is the SpamAssassin corpus, which contains hand-labeled spam messages contributed by Internet users. The remaining spam was collected by Project Honey Pot, a project that collects spam messages and identifies spammers by publishing email address that humans would know not to contact but that bots might target with spam. The full dataset we will use was constructed as roughly a 75/25 mix of the ham and spam messages.

The dataset contains just two fields:

- **text**: The text of the email.
- **spam**: A binary variable indicating if the email was spam.

Firsty, let us load the dataset and inspect its structure:

```
emails = read.csv("emails.csv", stringsAsFactors=FALSE)
str(emails)
```

```
## 'data.frame':    5728 obs. of  2 variables:
##  $ text: chr  "Subject: naturally irresistible your corporate identity  lt is really hard to recolle
##  $ spam: int  1 1 1 1 1 1 1 1 1 1 ...
```

We can observe the ham(no spam)-spam ratio in the dataset:

```
table(emails$spam)
```

```
##
##    0    1
## 4360 1368
```

Longest e-mail contains ~ 44k characters, which is evident using:

```
max(nchar(emails$text))
```

```
## [1] 43952
```

Shortest mail is located in the following line:

```
which.min(nchar(emails$text))
```

```
## [1] 1992
```

We will now use the **bag of words** approach to build a model. Following procedure given below we can build and pre-process the corpus:

```
#install.packages("tm")
library(tm)
```

```
## Warning: package 'tm' was built under R version 3.2.1
```

```
## Loading required package: NLP
```

```
## Warning: package 'NLP' was built under R version 3.2.1
```

```
corpus = Corpus(VectorSource(emails$text))

corpus=tm_map(corpus, tolower)
corpus = tm_map(corpus, PlainTextDocument)
corpus = tm_map(corpus, removePunctuation)
corpus = tm_map(corpus, removeWords, stopwords("english"))
corpus = tm_map(corpus, stemDocument)

dtm = DocumentTermMatrix(corpus)
dtm
```

```
## <<DocumentTermMatrix (documents: 5728, terms: 28687)>>
## Non-/sparse entries: 481719/163837417
## Sparsity           : 100%
## Maximal term length: 24
## Weighting          : term frequency (tf)
```

DTM matrix contains over 28k items. To obtain a more reasonable number of terms, we'll limit dtm to contain terms appearing in at least 5% of documents:

```
spdtm = removeSparseTerms(dtm, 0.95)
spdtm
```

```
## <<DocumentTermMatrix (documents: 5728, terms: 330)>>
## Non-/sparse entries: 213551/1676689
## Sparsity           : 89%
## Maximal term length: 10
## Weighting          : term frequency (tf)
```

From this, we can define new data frame `emailsSparse`.

```
emailsSparse = as.data.frame(as.matrix(spdtm))
colnames(emailsSparse) = make.names(colnames(emailsSparse))
```

The most frequent word stem is obtained with

```
sort(which.max(colSums(emailsSparse)))
```

```
## enron
##    92
```

Next, we want to add spam variable to the new datet.

```
emailsSparse$spam = emails$spam
```

We can find word stems that appear at least 5000 times in non-spam messages:

```
first = subset(emailsSparse, emailsSparse$spam==0)
sort(colSums(first)>5000) #or sum(colSums(first)>5000)
```

```
##       X000      X2000      X2001       X713       X853        abl
##      FALSE      FALSE      FALSE      FALSE      FALSE      FALSE
##     access    account      addit    address      allow    alreadi
##      FALSE      FALSE      FALSE      FALSE      FALSE      FALSE
##       also    analysi      anoth     applic    appreci     approv
##      FALSE      FALSE      FALSE      FALSE      FALSE      FALSE
##      april       area     arrang        ask     assist     associ
##      FALSE      FALSE      FALSE      FALSE      FALSE      FALSE
##     attach     attend      avail       back       base      begin
##      FALSE      FALSE      FALSE      FALSE      FALSE      FALSE
##     believ       best     better       book      bring       busi
##      FALSE      FALSE      FALSE      FALSE      FALSE      FALSE
##        buy       call        can       case      chang      check
##      FALSE      FALSE      FALSE      FALSE      FALSE      FALSE
##      click        com       come    comment   communic    compani
##      FALSE      FALSE      FALSE      FALSE      FALSE      FALSE
##    complet     confer    confirm    contact    continu   contract
##      FALSE      FALSE      FALSE      FALSE      FALSE      FALSE
##       copi       corp     corpor       cost      cours      creat
##      FALSE      FALSE      FALSE      FALSE      FALSE      FALSE
##     credit   crenshaw    current     custom       data       date
##      FALSE      FALSE      FALSE      FALSE      FALSE      FALSE
##        day       deal       dear     depart      deriv     design
##      FALSE      FALSE      FALSE      FALSE      FALSE      FALSE
##     detail    develop     differ     direct   director    discuss
##      FALSE      FALSE      FALSE      FALSE      FALSE      FALSE
##        doc        don       done        due        edu     effect
##      FALSE      FALSE      FALSE      FALSE      FALSE      FALSE
##     effort     either      email        end     energi      engin
##      FALSE      FALSE      FALSE      FALSE      FALSE      FALSE
##        etc       even      event     expect     experi        fax
##      FALSE      FALSE      FALSE      FALSE      FALSE      FALSE
```

```
##       feel       file      final     financ    financi       find
##      FALSE      FALSE      FALSE      FALSE      FALSE      FALSE
##      first     follow       form    forward       free     friday
##      FALSE      FALSE      FALSE      FALSE      FALSE      FALSE
##       full      futur        gas        get     gibner       give
##      FALSE      FALSE      FALSE      FALSE      FALSE      FALSE
##      given       good      great      group      happi       hear
##      FALSE      FALSE      FALSE      FALSE      FALSE      FALSE
##      hello       help       high       home       hope       hour
##      FALSE      FALSE      FALSE      FALSE      FALSE      FALSE
##    houston      howev       http       idea     immedi     import
##      FALSE      FALSE      FALSE      FALSE      FALSE      FALSE
##     includ    increas   industri       info     inform   interest
##      FALSE      FALSE      FALSE      FALSE      FALSE      FALSE
##     intern   internet  interview     invest      invit     involv
##      FALSE      FALSE      FALSE      FALSE      FALSE      FALSE
##       issu       john       join       juli       just   kaminski
##      FALSE      FALSE      FALSE      FALSE      FALSE      FALSE
##       keep      kevin       know       last        let       life
##      FALSE      FALSE      FALSE      FALSE      FALSE      FALSE
##       like       line       link       list      locat     london
##      FALSE      FALSE      FALSE      FALSE      FALSE      FALSE
##       long       look        lot       made       mail       make
##      FALSE      FALSE      FALSE      FALSE      FALSE      FALSE
##      manag       mani       mark     market        may       mean
##      FALSE      FALSE      FALSE      FALSE      FALSE      FALSE
##       meet     member    mention     messag      might      model
##      FALSE      FALSE      FALSE      FALSE      FALSE      FALSE
##     monday      money      month       morn       move       much
##      FALSE      FALSE      FALSE      FALSE      FALSE      FALSE
##       name       need        net        new      next.       note
##      FALSE      FALSE      FALSE      FALSE      FALSE      FALSE
##        now     number      offer      offic        one      onlin
##      FALSE      FALSE      FALSE      FALSE      FALSE      FALSE
##       open       oper   opportun     option      order     origin
##      FALSE      FALSE      FALSE      FALSE      FALSE      FALSE
##       part   particip      peopl        per     person      phone
##      FALSE      FALSE      FALSE      FALSE      FALSE      FALSE
##      place       plan      pleas      point      posit    possibl
##      FALSE      FALSE      FALSE      FALSE      FALSE      FALSE
##      power    present      price    problem    process    product
##      FALSE      FALSE      FALSE      FALSE      FALSE      FALSE
##    program    project     provid     public        put   question
##      FALSE      FALSE      FALSE      FALSE      FALSE      FALSE
##       rate       read       real     realli     receiv     recent
##      FALSE      FALSE      FALSE      FALSE      FALSE      FALSE
##     regard      relat      remov      repli     report    request
##      FALSE      FALSE      FALSE      FALSE      FALSE      FALSE
##     requir   research    resourc    respond    respons     result
##      FALSE      FALSE      FALSE      FALSE      FALSE      FALSE
##      resum     return     review      right       risk     robert
##      FALSE      FALSE      FALSE      FALSE      FALSE      FALSE
##        run        say    schedul     school      secur        see
##      FALSE      FALSE      FALSE      FALSE      FALSE      FALSE
```

```
##       send       sent     servic        set      sever      shall
##      FALSE      FALSE      FALSE      FALSE      FALSE      FALSE
##    shirley      short       sinc     sincer       site    softwar
##      FALSE      FALSE      FALSE      FALSE      FALSE      FALSE
##       soon      sorri    special     specif      start      state
##      FALSE      FALSE      FALSE      FALSE      FALSE      FALSE
##      still    stinson    student    success    suggest    support
##      FALSE      FALSE      FALSE      FALSE      FALSE      FALSE
##       sure     system       take       talk       team       term
##      FALSE      FALSE      FALSE      FALSE      FALSE      FALSE
##      thank      thing      think    thought   thursday       time
##      FALSE      FALSE      FALSE      FALSE      FALSE      FALSE
##      today     togeth      trade        tri    tuesday        two
##      FALSE      FALSE      FALSE      FALSE      FALSE      FALSE
##       type understand       unit    univers      updat        use
##      FALSE      FALSE      FALSE      FALSE      FALSE      FALSE
##       valu    version      visit     vkamin       want        way
##      FALSE      FALSE      FALSE      FALSE      FALSE      FALSE
##        web     websit  wednesday       week       well       wish
##      FALSE      FALSE      FALSE      FALSE      FALSE      FALSE
##     within    without       work      write        www       year
##      FALSE      FALSE      FALSE      FALSE      FALSE      FALSE
##       spam        ect      enron        hou    subject       vinc
##      FALSE       TRUE       TRUE       TRUE       TRUE       TRUE
##       will
##       TRUE
```

Likewise, we can determine word stems that appear at least 1000 times in spam messages:

```
firstspam = subset(emailsSparse, emailsSparse$spam==1)
sort(colSums(firstspam)>=1000)
```

```
##       X000      X2000      X2001       X713       X853        abl
##      FALSE      FALSE      FALSE      FALSE      FALSE      FALSE
##     access    account      addit    address      allow    alreadi
##      FALSE      FALSE      FALSE      FALSE      FALSE      FALSE
##       also    analysi      anoth     applic    appreci     approv
##      FALSE      FALSE      FALSE      FALSE      FALSE      FALSE
##      april       area     arrang        ask     assist     associ
##      FALSE      FALSE      FALSE      FALSE      FALSE      FALSE
##     attach     attend      avail       back       base      begin
##      FALSE      FALSE      FALSE      FALSE      FALSE      FALSE
##     believ       best     better       book      bring       busi
##      FALSE      FALSE      FALSE      FALSE      FALSE      FALSE
##        buy       call        can       case      chang      check
##      FALSE      FALSE      FALSE      FALSE      FALSE      FALSE
##      click        com       come    comment   communic    complet
##      FALSE      FALSE      FALSE      FALSE      FALSE      FALSE
##     confer    confirm    contact    continu   contract       copi
##      FALSE      FALSE      FALSE      FALSE      FALSE      FALSE
##       corp     corpor       cost      cours      creat     credit
##      FALSE      FALSE      FALSE      FALSE      FALSE      FALSE
##   crenshaw    current     custom       data       date        day
```

```
##      FALSE      FALSE      FALSE      FALSE      FALSE      FALSE
##       deal       dear     depart      deriv     design     detail
##      FALSE      FALSE      FALSE      FALSE      FALSE      FALSE
##    develop     differ     direct   director    discuss        doc
##      FALSE      FALSE      FALSE      FALSE      FALSE      FALSE
##        don       done        due        ect        edu     effect
##      FALSE      FALSE      FALSE      FALSE      FALSE      FALSE
##     effort     either      email        end     energi      engin
##      FALSE      FALSE      FALSE      FALSE      FALSE      FALSE
##      enron        etc       even      event     expect     experi
##      FALSE      FALSE      FALSE      FALSE      FALSE      FALSE
##        fax       feel       file      final     financ    financi
##      FALSE      FALSE      FALSE      FALSE      FALSE      FALSE
##       find      first     follow       form    forward       free
##      FALSE      FALSE      FALSE      FALSE      FALSE      FALSE
##     friday       full      futur        gas        get     gibner
##      FALSE      FALSE      FALSE      FALSE      FALSE      FALSE
##       give      given       good      great      group      happi
##      FALSE      FALSE      FALSE      FALSE      FALSE      FALSE
##       hear      hello       help       high       home       hope
##      FALSE      FALSE      FALSE      FALSE      FALSE      FALSE
##        hou       hour    houston      howev       http       idea
##      FALSE      FALSE      FALSE      FALSE      FALSE      FALSE
##     immedi     import     includ    increas   industri       info
##      FALSE      FALSE      FALSE      FALSE      FALSE      FALSE
##     inform   interest     intern   internet  interview     invest
##      FALSE      FALSE      FALSE      FALSE      FALSE      FALSE
##      invit     involv       issu       john       join       juli
##      FALSE      FALSE      FALSE      FALSE      FALSE      FALSE
##       just   kaminski       keep      kevin       know       last
##      FALSE      FALSE      FALSE      FALSE      FALSE      FALSE
##        let       life       like       line       link       list
##      FALSE      FALSE      FALSE      FALSE      FALSE      FALSE
##      locat     london       long       look        lot       made
##      FALSE      FALSE      FALSE      FALSE      FALSE      FALSE
##       mail       make      manag       mani       mark     market
##      FALSE      FALSE      FALSE      FALSE      FALSE      FALSE
##        may       mean       meet     member    mention     messag
##      FALSE      FALSE      FALSE      FALSE      FALSE      FALSE
##      might      model     monday      money      month       morn
##      FALSE      FALSE      FALSE      FALSE      FALSE      FALSE
##       move       much       name       need        net        new
##      FALSE      FALSE      FALSE      FALSE      FALSE      FALSE
##      next.       note        now     number      offer      offic
##      FALSE      FALSE      FALSE      FALSE      FALSE      FALSE
##        one      onlin       open       oper   opportun     option
##      FALSE      FALSE      FALSE      FALSE      FALSE      FALSE
##      order     origin       part   particip      peopl        per
##      FALSE      FALSE      FALSE      FALSE      FALSE      FALSE
##     person      phone      place       plan      pleas      point
##      FALSE      FALSE      FALSE      FALSE      FALSE      FALSE
##      posit    possibl      power    present      price    problem
##      FALSE      FALSE      FALSE      FALSE      FALSE      FALSE
##    process    product    program    project     provid     public
```

```
##      FALSE      FALSE      FALSE      FALSE      FALSE      FALSE
##        put   question       rate       read       real     realli
##      FALSE      FALSE      FALSE      FALSE      FALSE      FALSE
##     receiv     recent     regard      relat      remov      repli
##      FALSE      FALSE      FALSE      FALSE      FALSE      FALSE
##     report    request     requir   research    resourc    respond
##      FALSE      FALSE      FALSE      FALSE      FALSE      FALSE
##    respons     result      resum     return     review      right
##      FALSE      FALSE      FALSE      FALSE      FALSE      FALSE
##       risk     robert        run        say    schedul     school
##      FALSE      FALSE      FALSE      FALSE      FALSE      FALSE
##      secur        see       send       sent     servic        set
##      FALSE      FALSE      FALSE      FALSE      FALSE      FALSE
##      sever      shall    shirley      short       sinc     sincer
##      FALSE      FALSE      FALSE      FALSE      FALSE      FALSE
##       site    softwar       soon      sorri    special     specif
##      FALSE      FALSE      FALSE      FALSE      FALSE      FALSE
##      start      state      still    stinson    student    success
##      FALSE      FALSE      FALSE      FALSE      FALSE      FALSE
##    suggest    support       sure     system       take       talk
##      FALSE      FALSE      FALSE      FALSE      FALSE      FALSE
##       team       term      thank      thing      think    thought
##      FALSE      FALSE      FALSE      FALSE      FALSE      FALSE
##   thursday       time      today     togeth      trade        tri
##      FALSE      FALSE      FALSE      FALSE      FALSE      FALSE
##    tuesday        two       type understand       unit    univers
##      FALSE      FALSE      FALSE      FALSE      FALSE      FALSE
##      updat        use       valu    version       vinc      visit
##      FALSE      FALSE      FALSE      FALSE      FALSE      FALSE
##     vkamin       want        way        web     websit  wednesday
##      FALSE      FALSE      FALSE      FALSE      FALSE      FALSE
##       week       well       wish     within    without       work
##      FALSE      FALSE      FALSE      FALSE      FALSE      FALSE
##      write        www       year    compani    subject       will
##      FALSE      FALSE      FALSE       TRUE       TRUE       TRUE
##       spam
##       TRUE
```

After this quick analysis, we can start building our models:

Firstly, we must set `spam` variable to be a factor:

```
emailsSparse$spam = as.factor(emailsSparse$spam)
```

Next, we'll devide dateset into training and testing:

```
#install.packages("caTools")
library(caTools)
```

```
## Warning: package 'caTools' was built under R version 3.2.1
```

```
set.seed(123)
spl = sample.split(emailsSparse$spam, SplitRatio = 0.7)
train = subset(emailsSparse, spl == T)
test = subset(emailsSparse, spl == F)
```

Using the training set, we'll train the following three machine learning models. The models should predict the dependent variable "spam", using all other available variables as independent variables.

1) Logistic regression

```
spamLog = glm(spam ~., data=train, family="binomial")
```

```
## Warning: glm.fit: algorithm did not converge
```

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

```
pred = predict(spamLog, type="response")
```

2) CART model

```
# install.packages("rpart")
library(rpart)
spamCART = rpart(spam~., data=train, method="class")
predCART = predict(spamCART)
predCART.prob = predCART[,2]
```

3) Random Forest

```
# install.packages("randomForest")
library(randomForest)
```

```
## Warning: package 'randomForest' was built under R version 3.2.1
```

```
## randomForest 4.6-10
## Type rfNews() to see new features/changes/bug fixes.
```

```
set.seed(123)
spamRF =  randomForest(spam~., data=train)
predRF = predict(spamRF, type = "prob")
predRF.prob = predRF[,2]
```

Interestingly, we find that none of the variables are labeled as significant (at the p=0.05 level) for logistic regression:

```
summary(spamLog)
```

```
##
## Call:
## glm(formula = spam ~ ., family = "binomial", data = train)
##
## Deviance Residuals:
##    Min      1Q  Median      3Q     Max
## -1.011   0.000   0.000   0.000   1.354
##
## Coefficients:
##               Estimate Std. Error z value Pr(>|z|)
## (Intercept) -3.082e+01  1.055e+04  -0.003    0.998
## X000         1.474e+01  1.058e+04   0.001    0.999
## X2000       -3.631e+01  1.556e+04  -0.002    0.998
## X2001       -3.215e+01  1.318e+04  -0.002    0.998
## X713        -2.427e+01  2.914e+04  -0.001    0.999
## X853        -1.212e+00  5.942e+04   0.000    1.000
## abl         -2.049e+00  2.088e+04   0.000    1.000
## access      -1.480e+01  1.335e+04  -0.001    0.999
## account      2.488e+01  8.165e+03   0.003    0.998
## addit        1.463e+00  2.703e+04   0.000    1.000
## address     -4.613e+00  1.113e+04   0.000    1.000
## allow        1.899e+01  6.436e+03   0.003    0.998
## alreadi     -2.407e+01  3.319e+04  -0.001    0.999
## also         2.990e+01  1.378e+04   0.002    0.998
## analysi     -2.405e+01  3.860e+04  -0.001    1.000
## anoth       -8.744e+00  2.032e+04   0.000    1.000
## applic      -2.649e+00  1.674e+04   0.000    1.000
## appreci     -2.145e+01  2.762e+04  -0.001    0.999
## approv      -1.302e+00  1.589e+04   0.000    1.000
## april       -2.620e+01  2.208e+04  -0.001    0.999
## area         2.041e+01  2.266e+04   0.001    0.999
## arrang       1.069e+01  2.135e+04   0.001    1.000
## ask         -7.746e+00  1.976e+04   0.000    1.000
## assist      -1.128e+01  2.490e+04   0.000    1.000
## associ       9.049e+00  1.909e+04   0.000    1.000
## attach      -1.037e+01  1.534e+04  -0.001    0.999
## attend      -3.451e+01  3.257e+04  -0.001    0.999
## avail        8.651e+00  1.709e+04   0.001    1.000
## back        -1.323e+01  2.272e+04  -0.001    1.000
## base        -1.354e+01  2.122e+04  -0.001    0.999
## begin        2.228e+01  2.973e+04   0.001    0.999
## believ       3.233e+01  2.136e+04   0.002    0.999
## best        -8.201e+00  1.333e+03  -0.006    0.995
## better       4.263e+01  2.360e+04   0.002    0.999
## book         4.301e+00  2.024e+04   0.000    1.000
## bring        1.607e+01  6.767e+04   0.000    1.000
## busi        -4.803e+00  1.000e+04   0.000    1.000
## buy          4.170e+01  3.892e+04   0.001    0.999
## call        -1.145e+00  1.111e+04   0.000    1.000
## can          3.762e+00  7.674e+03   0.000    1.000
## case        -3.372e+01  2.880e+04  -0.001    0.999
## chang       -2.717e+01  2.215e+04  -0.001    0.999
## check        1.425e+00  1.963e+04   0.000    1.000
## click        1.376e+01  7.077e+03   0.002    0.998
```

```
## com          1.936e+00  4.039e+03   0.000    1.000
## come        -1.166e+00  1.511e+04   0.000    1.000
## comment     -3.251e+00  3.387e+04   0.000    1.000
## communic     1.580e+01  8.958e+03   0.002    0.999
## compani      4.781e+00  9.186e+03   0.001    1.000
## complet     -1.363e+01  2.024e+04  -0.001    0.999
## confer      -7.503e-01  8.557e+03   0.000    1.000
## confirm     -1.300e+01  1.514e+04  -0.001    0.999
## contact      1.530e+00  1.262e+04   0.000    1.000
## continu      1.487e+01  1.535e+04   0.001    0.999
## contract    -1.295e+01  1.498e+04  -0.001    0.999
## copi        -4.274e+01  3.070e+04  -0.001    0.999
## corp         1.606e+01  2.708e+04   0.001    1.000
## corpor      -8.286e-01  2.818e+04   0.000    1.000
## cost        -1.938e+00  1.833e+04   0.000    1.000
## cours        1.665e+01  1.834e+04   0.001    0.999
## creat        1.338e+01  3.946e+04   0.000    1.000
## credit       2.617e+01  1.314e+04   0.002    0.998
## crenshaw     9.994e+01  6.769e+04   0.001    0.999
## current      3.629e+00  1.707e+04   0.000    1.000
## custom       1.829e+01  1.008e+04   0.002    0.999
## data        -2.609e+01  2.271e+04  -0.001    0.999
## date        -2.786e+00  1.699e+04   0.000    1.000
## day         -6.100e+00  5.866e+03  -0.001    0.999
## deal        -1.129e+01  1.448e+04  -0.001    0.999
## dear        -2.313e+00  2.306e+04   0.000    1.000
## depart      -4.068e+01  2.509e+04  -0.002    0.999
## deriv       -4.971e+01  3.587e+04  -0.001    0.999
## design      -7.923e+00  2.939e+04   0.000    1.000
## detail       1.197e+01  2.301e+04   0.001    1.000
## develop      5.976e+00  9.455e+03   0.001    0.999
## differ      -2.293e+00  1.075e+04   0.000    1.000
## direct      -2.051e+01  3.194e+04  -0.001    0.999
## director    -1.770e+01  1.793e+04  -0.001    0.999
## discuss     -1.051e+01  1.915e+04  -0.001    1.000
## doc         -2.597e+01  2.603e+04  -0.001    0.999
## don          2.129e+01  1.456e+04   0.001    0.999
## done         6.828e+00  1.882e+04   0.000    1.000
## due         -4.163e+00  3.532e+04   0.000    1.000
## ect          8.685e-01  5.342e+03   0.000    1.000
## edu         -2.122e-01  6.917e+02   0.000    1.000
## effect       1.948e+01  2.100e+04   0.001    0.999
## effort       1.606e+01  5.670e+04   0.000    1.000
## either      -2.744e+01  4.000e+04  -0.001    0.999
## email        3.833e+00  1.186e+04   0.000    1.000
## end         -1.311e+01  2.938e+04   0.000    1.000
## energi      -1.620e+01  1.646e+04  -0.001    0.999
## engin        2.664e+01  2.394e+04   0.001    0.999
## enron       -8.789e+00  5.719e+03  -0.002    0.999
## etc          9.470e-01  1.569e+04   0.000    1.000
## even        -1.654e+01  2.289e+04  -0.001    0.999
## event        1.694e+01  1.851e+04   0.001    0.999
## expect      -1.179e+01  1.914e+04  -0.001    1.000
## experi       2.460e+00  2.240e+04   0.000    1.000
```

```
## fax          3.537e+00  3.386e+04   0.000    1.000
## feel         2.596e+00  2.348e+04   0.000    1.000
## file        -2.943e+01  2.165e+04  -0.001    0.999
## final        8.075e+00  5.008e+04   0.000    1.000
## financ      -9.122e+00  7.524e+03  -0.001    0.999
## financi     -9.747e+00  1.727e+04  -0.001    1.000
## find        -2.623e+00  9.727e+03   0.000    1.000
## first       -4.666e-01  2.043e+04   0.000    1.000
## follow       1.766e+01  3.080e+03   0.006    0.995
## form         8.483e+00  1.674e+04   0.001    1.000
## forward     -3.484e+00  1.864e+04   0.000    1.000
## free         6.113e+00  8.121e+03   0.001    0.999
## friday      -1.146e+01  1.996e+04  -0.001    1.000
## full         2.125e+01  2.190e+04   0.001    0.999
## futur        4.146e+01  1.439e+04   0.003    0.998
## gas         -3.901e+00  4.160e+03  -0.001    0.999
## get          5.154e+00  9.737e+03   0.001    1.000
## gibner       2.901e+01  2.460e+04   0.001    0.999
## give        -2.518e+01  2.130e+04  -0.001    0.999
## given       -2.186e+01  5.426e+04   0.000    1.000
## good         5.399e+00  1.619e+04   0.000    1.000
## great        1.222e+01  1.090e+04   0.001    0.999
## group        5.264e-01  1.037e+04   0.000    1.000
## happi        1.939e-02  1.202e+04   0.000    1.000
## hear         2.887e+01  2.281e+04   0.001    0.999
## hello        2.166e+01  1.361e+04   0.002    0.999
## help         1.731e+01  2.791e+03   0.006    0.995
## high        -1.982e+00  2.554e+04   0.000    1.000
## home         5.973e+00  8.965e+03   0.001    0.999
## hope        -1.435e+01  2.179e+04  -0.001    0.999
## hou          6.852e+00  6.437e+03   0.001    0.999
## hour         2.478e+00  1.333e+04   0.000    1.000
## houston     -1.855e+01  7.305e+03  -0.003    0.998
## howev       -3.449e+01  3.562e+04  -0.001    0.999
## http         2.528e+01  2.107e+04   0.001    0.999
## idea        -1.845e+01  3.892e+04   0.000    1.000
## immedi       6.285e+01  3.346e+04   0.002    0.999
## import      -1.859e+00  2.236e+04   0.000    1.000
## includ      -3.454e+00  1.799e+04   0.000    1.000
## increas      6.476e+00  2.329e+04   0.000    1.000
## industri    -3.160e+01  2.373e+04  -0.001    0.999
## info        -1.255e+00  4.857e+03   0.000    1.000
## inform       2.078e+01  8.549e+03   0.002    0.998
## interest     2.698e+01  1.159e+04   0.002    0.998
## intern      -7.991e+00  3.351e+04   0.000    1.000
## internet     8.749e+00  1.100e+04   0.001    0.999
## interview   -1.640e+01  1.873e+04  -0.001    0.999
## invest       3.201e+01  2.393e+04   0.001    0.999
## invit        4.304e+00  2.215e+04   0.000    1.000
## involv       3.815e+01  3.315e+04   0.001    0.999
## issu        -3.708e+01  3.396e+04  -0.001    0.999
## john        -5.326e-01  2.856e+04   0.000    1.000
## join        -3.824e+01  2.334e+04  -0.002    0.999
## juli        -1.358e+01  3.009e+04   0.000    1.000
```

```
## just        -1.021e+01  1.114e+04  -0.001    0.999
## kaminski    -1.812e+01  6.029e+03  -0.003    0.998
## keep         1.867e+01  2.782e+04   0.001    0.999
## kevin       -3.779e+01  4.738e+04  -0.001    0.999
## know         1.277e+01  1.526e+04   0.001    0.999
## last         1.046e+00  1.372e+04   0.000    1.000
## let         -2.763e+01  1.462e+04  -0.002    0.998
## life         5.812e+01  3.864e+04   0.002    0.999
## like         5.649e+00  7.660e+03   0.001    0.999
## line         8.743e+00  1.236e+04   0.001    0.999
## link        -6.929e+00  1.345e+04  -0.001    1.000
## list        -8.692e+00  2.149e+03  -0.004    0.997
## locat        2.073e+01  1.597e+04   0.001    0.999
## london       6.745e+00  1.642e+04   0.000    1.000
## long        -1.489e+01  1.934e+04  -0.001    0.999
## look        -7.031e+00  1.563e+04   0.000    1.000
## lot         -1.964e+01  1.321e+04  -0.001    0.999
## made         2.820e+00  2.743e+04   0.000    1.000
## mail         7.584e+00  1.021e+04   0.001    0.999
## make         2.901e+01  1.528e+04   0.002    0.998
## manag        6.014e+00  1.445e+04   0.000    1.000
## mani         1.885e+01  1.442e+04   0.001    0.999
## mark        -3.350e+01  3.208e+04  -0.001    0.999
## market       7.895e+00  8.012e+03   0.001    0.999
## may         -9.434e+00  1.397e+04  -0.001    0.999
## mean         6.078e-01  2.952e+04   0.000    1.000
## meet        -1.063e+00  1.263e+04   0.000    1.000
## member       1.381e+01  2.343e+04   0.001    1.000
## mention     -2.279e+01  2.714e+04  -0.001    0.999
## messag       1.716e+01  2.562e+03   0.007    0.995
## might        1.244e+01  1.753e+04   0.001    0.999
## model       -2.292e+01  1.049e+04  -0.002    0.998
## monday      -1.034e+00  3.233e+04   0.000    1.000
## money        3.264e+01  1.321e+04   0.002    0.998
## month       -3.727e+00  1.112e+04   0.000    1.000
## morn        -2.645e+01  3.403e+04  -0.001    0.999
## move        -3.834e+01  3.011e+04  -0.001    0.999
## much         3.775e-01  1.392e+04   0.000    1.000
## name         1.672e+01  1.322e+04   0.001    0.999
## need         8.437e-01  1.221e+04   0.000    1.000
## net          1.256e+01  2.197e+04   0.001    1.000
## new          1.003e+00  1.009e+04   0.000    1.000
## next.        1.492e+01  1.724e+04   0.001    0.999
## note         1.446e+01  2.294e+04   0.001    0.999
## now          3.790e+01  1.219e+04   0.003    0.998
## number      -9.622e+00  1.591e+04  -0.001    1.000
## offer        1.174e+01  1.084e+04   0.001    0.999
## offic       -1.344e+01  2.311e+04  -0.001    1.000
## one          1.241e+01  6.652e+03   0.002    0.999
## onlin        3.589e+01  1.665e+04   0.002    0.998
## open         2.114e+01  2.961e+04   0.001    0.999
## oper        -1.696e+01  2.757e+04  -0.001    1.000
## opportun    -4.131e+00  1.918e+04   0.000    1.000
## option      -1.085e+00  9.325e+03   0.000    1.000
```

```
## order        6.533e+00  1.242e+04   0.001    1.000
## origin       3.226e+01  3.818e+04   0.001    0.999
## part         4.594e+00  3.483e+04   0.000    1.000
## particip    -1.154e+01  1.738e+04  -0.001    0.999
## peopl       -1.864e+01  1.439e+04  -0.001    0.999
## per          1.367e+01  1.273e+04   0.001    0.999
## person       1.870e+01  9.575e+03   0.002    0.998
## phone       -6.957e+00  1.172e+04  -0.001    1.000
## place        9.005e+00  3.661e+04   0.000    1.000
## plan        -1.830e+01  6.320e+03  -0.003    0.998
## pleas       -7.961e+00  9.484e+03  -0.001    0.999
## point        5.498e+00  3.403e+04   0.000    1.000
## posit       -1.543e+01  2.316e+04  -0.001    0.999
## possibl     -1.366e+01  2.492e+04  -0.001    1.000
## power       -5.643e+00  1.173e+04   0.000    1.000
## present     -6.163e+00  1.278e+04   0.000    1.000
## price        3.428e+00  7.850e+03   0.000    1.000
## problem      1.262e+01  9.763e+03   0.001    0.999
## process     -2.957e-01  1.191e+04   0.000    1.000
## product      1.016e+01  1.345e+04   0.001    0.999
## program      1.444e+00  1.183e+04   0.000    1.000
## project      2.173e+00  1.497e+04   0.000    1.000
## provid       2.422e-01  1.859e+04   0.000    1.000
## public      -5.250e+01  2.341e+04  -0.002    0.998
## put         -1.052e+01  2.681e+04   0.000    1.000
## question    -3.467e+01  1.859e+04  -0.002    0.999
## rate        -3.112e+00  1.319e+04   0.000    1.000
## read        -1.527e+01  2.145e+04  -0.001    0.999
## real         2.046e+01  2.358e+04   0.001    0.999
## realli      -2.667e+01  4.640e+04  -0.001    1.000
## receiv       5.765e-01  1.585e+04   0.000    1.000
## recent      -2.067e+00  1.780e+04   0.000    1.000
## regard      -3.668e+00  1.511e+04   0.000    1.000
## relat       -5.114e+01  1.793e+04  -0.003    0.998
## remov        2.325e+01  2.484e+04   0.001    0.999
## repli        1.538e+01  2.916e+04   0.001    1.000
## report      -1.482e+01  1.477e+04  -0.001    0.999
## request     -1.232e+01  1.167e+04  -0.001    0.999
## requir       5.004e-01  2.937e+04   0.000    1.000
## research    -2.826e+01  1.553e+04  -0.002    0.999
## resourc     -2.735e+01  3.522e+04  -0.001    0.999
## respond      2.974e+01  3.888e+04   0.001    0.999
## respons     -1.960e+01  3.667e+04  -0.001    1.000
## result      -5.002e-01  3.140e+04   0.000    1.000
## resum       -9.219e+00  2.100e+04   0.000    1.000
## return       1.745e+01  1.844e+04   0.001    0.999
## review      -4.825e+00  1.013e+04   0.000    1.000
## right        2.312e+01  1.590e+04   0.001    0.999
## risk        -4.001e+00  1.718e+04   0.000    1.000
## robert      -2.096e+01  2.907e+04  -0.001    0.999
## run         -5.162e+01  4.434e+04  -0.001    0.999
## say          7.366e+00  2.217e+04   0.000    1.000
## schedul      1.919e+00  3.580e+04   0.000    1.000
## school      -3.870e+00  2.882e+04   0.000    1.000
```

```
## secur       -1.604e+01  2.201e+03  -0.007    0.994
## see         -1.120e+01  1.293e+04  -0.001    0.999
## send        -2.427e+01  1.222e+04  -0.002    0.998
## sent        -1.488e+01  2.195e+04  -0.001    0.999
## servic      -7.164e+00  1.235e+04  -0.001    1.000
## set         -9.353e+00  2.627e+04   0.000    1.000
## sever        2.041e+01  3.093e+04   0.001    0.999
## shall        1.930e+01  3.075e+04   0.001    0.999
## shirley     -7.133e+01  6.329e+04  -0.001    0.999
## short       -8.974e+00  1.721e+04  -0.001    1.000
## sinc        -3.438e+00  3.546e+04   0.000    1.000
## sincer      -2.073e+01  3.515e+04  -0.001    1.000
## site         8.689e+00  1.496e+04   0.001    1.000
## softwar      2.575e+01  1.059e+04   0.002    0.998
## soon         2.350e+01  3.731e+04   0.001    0.999
## sorri        6.036e+00  2.299e+04   0.000    1.000
## special      1.777e+01  2.755e+04   0.001    0.999
## specif      -2.337e+01  3.083e+04  -0.001    0.999
## start        1.437e+01  1.897e+04   0.001    0.999
## state        1.221e+01  1.677e+04   0.001    0.999
## still        3.878e+00  2.622e+04   0.000    1.000
## stinson     -4.345e+01  2.697e+04  -0.002    0.999
## student     -1.815e+01  2.186e+04  -0.001    0.999
## subject      3.041e+01  1.055e+04   0.003    0.998
## success      4.344e+00  2.783e+04   0.000    1.000
## suggest     -3.842e+01  4.475e+04  -0.001    0.999
## support     -1.539e+01  1.976e+04  -0.001    0.999
## sure        -5.503e+00  2.078e+04   0.000    1.000
## system       3.778e+00  9.149e+03   0.000    1.000
## take         5.731e+00  1.716e+04   0.000    1.000
## talk        -1.011e+01  2.021e+04  -0.001    1.000
## team         7.940e+00  2.570e+04   0.000    1.000
## term         2.013e+01  2.303e+04   0.001    0.999
## thank       -3.890e+01  1.059e+04  -0.004    0.997
## thing        2.579e+01  1.341e+04   0.002    0.998
## think       -1.218e+01  2.077e+04  -0.001    1.000
## thought      1.243e+01  3.023e+04   0.000    1.000
## thursday    -1.491e+01  3.262e+04   0.000    1.000
## time        -5.921e+00  8.335e+03  -0.001    0.999
## today       -1.762e+01  1.965e+04  -0.001    0.999
## togeth      -2.355e+01  1.869e+04  -0.001    0.999
## trade       -1.755e+01  1.483e+04  -0.001    0.999
## tri          9.278e-01  1.282e+04   0.000    1.000
## tuesday     -2.808e+01  3.959e+04  -0.001    0.999
## two         -2.573e+01  1.844e+04  -0.001    0.999
## type        -1.447e+01  2.755e+04  -0.001    1.000
## understand   9.307e+00  2.342e+04   0.000    1.000
## unit        -4.020e+00  3.008e+04   0.000    1.000
## univers      1.228e+01  2.197e+04   0.001    1.000
## updat       -1.510e+01  1.448e+04  -0.001    0.999
## use         -1.385e+01  9.382e+03  -0.001    0.999
## valu         9.024e-01  1.360e+04   0.000    1.000
## version     -3.606e+01  2.939e+04  -0.001    0.999
## vinc        -3.735e+01  8.647e+03  -0.004    0.997
```

```
## visit        2.585e+01  1.170e+04   0.002    0.998
## vkamin      -6.649e+01  5.703e+04  -0.001    0.999
## want        -2.555e+00  1.106e+04   0.000    1.000
## way          1.339e+01  1.138e+04   0.001    0.999
## web          2.791e+00  1.686e+04   0.000    1.000
## websit      -2.563e+01  1.848e+04  -0.001    0.999
## wednesday   -1.526e+01  2.642e+04  -0.001    1.000
## week        -6.795e+00  1.046e+04  -0.001    0.999
## well        -2.222e+01  9.713e+03  -0.002    0.998
## will        -1.119e+01  5.980e+03  -0.002    0.999
## wish         1.173e+01  3.175e+04   0.000    1.000
## within       2.900e+01  2.163e+04   0.001    0.999
## without      1.942e+01  1.763e+04   0.001    0.999
## work        -1.099e+01  1.160e+04  -0.001    0.999
## write        4.406e+01  2.825e+04   0.002    0.999
## www         -7.867e+00  2.224e+04   0.000    1.000
## year        -1.010e+01  1.039e+04  -0.001    0.999
##
## (Dispersion parameter for binomial family taken to be 1)
##
##     Null deviance: 4409.49  on 4009  degrees of freedom
## Residual deviance:   13.46  on 3679  degrees of freedom
## AIC: 675.46
##
## Number of Fisher Scoring iterations: 25
```

However, we find that the accuracyof the model is pretty high:

```
table(train$spam, pred>0.5)
```

```
##
##     FALSE TRUE
##   0  3052    0
##   1     4  954
```

```
(3052+954)/(3052+954+4)
```

```
## [1] 0.9990025
```

This can also be confirmed with AUC number:

```
# install.packages("ROCR")
library(ROCR)
```

```
## Warning: package 'ROCR' was built under R version 3.2.1
```

```
## Loading required package: gplots
```

```
## Warning: package 'gplots' was built under R version 3.2.1
```

```
##
## Attaching package: 'gplots'
##
## The following object is masked from 'package:stats':
##
##     lowess
```

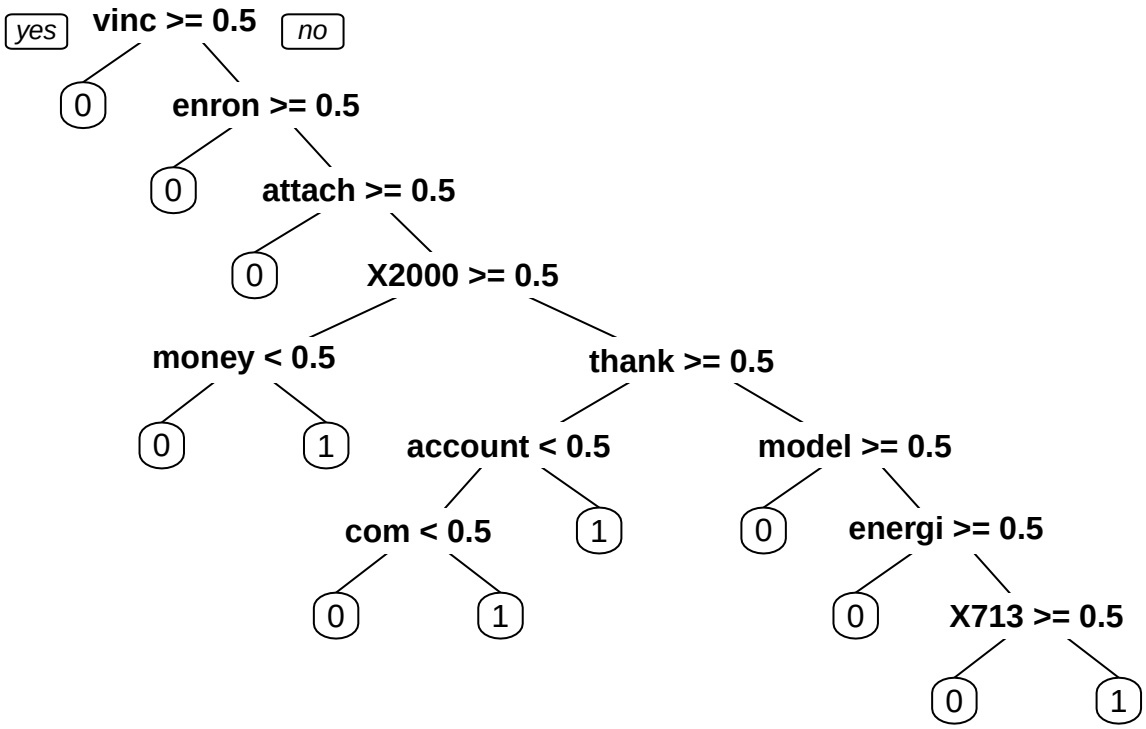
```
predROCR = prediction(pred, train$spam)

AUC = as.numeric(performance(predROCR, "auc")@y.values)
AUC
```

```
## [1] 0.9999959
```

For our CART model, we should first plot the CART tree to see how many levels it got.

```
# install.packages("rpart.plot")
library(rpart.plot)
prp(spamCART)
```



The accuracy for this model can be easily calculated:

```
table(train$spam, predCART.prob>0.5 )
```

```
##
```

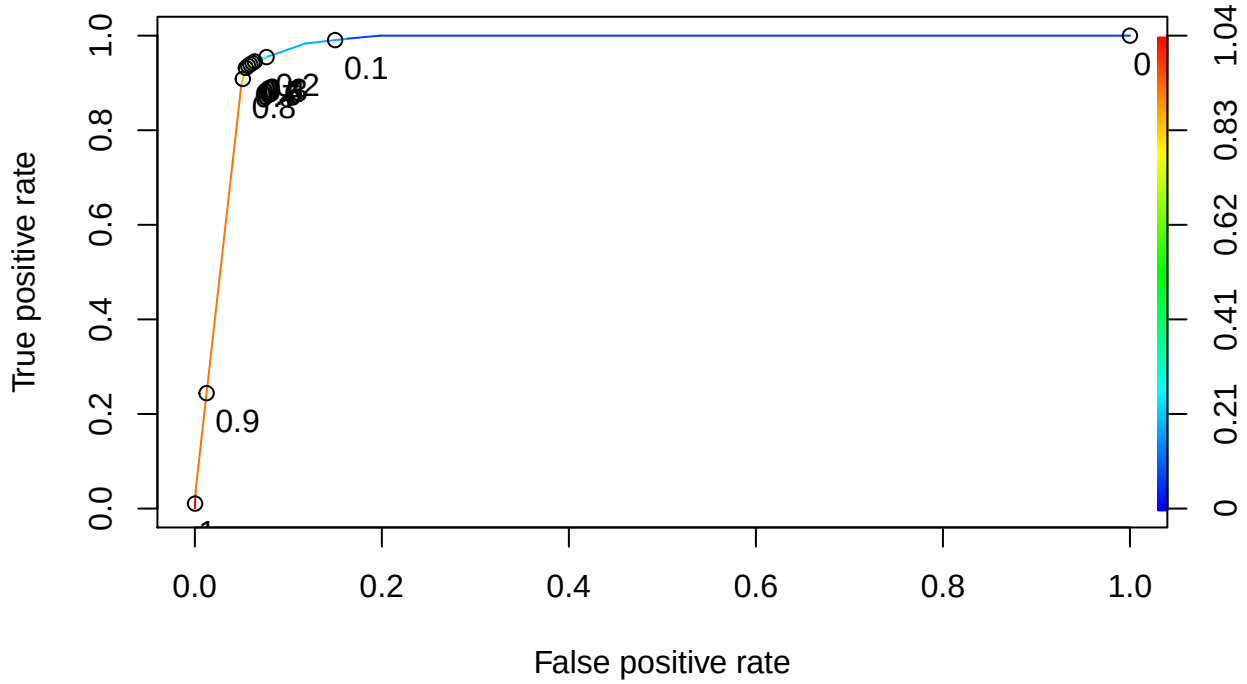
```
##     FALSE TRUE
##   0  2885  167
##   1    64  894
```

```
(2885+894)/nrow(train)
```

```
## [1] 0.942394
```

The AUC for CART model is calculated as follows:

```
predROCR = prediction(predCART.prob, train$spam)
ROCRperf=performance(predROCR, "tpr", "fpr")
plot(ROCRperf, colorize=T, print.cutoffs.at=seq(0,1,0.1), text.adj=c(-0.2,1.7))
```




```
AUC = as.numeric(performance(predROCR, "auc")@y.values)
AUC
```

```
## [1] 0.9696044
```

Finally, we can obtain accuracy of our Random Forest model:

```
table(train$spam, predRF.prob>0.5 )
```

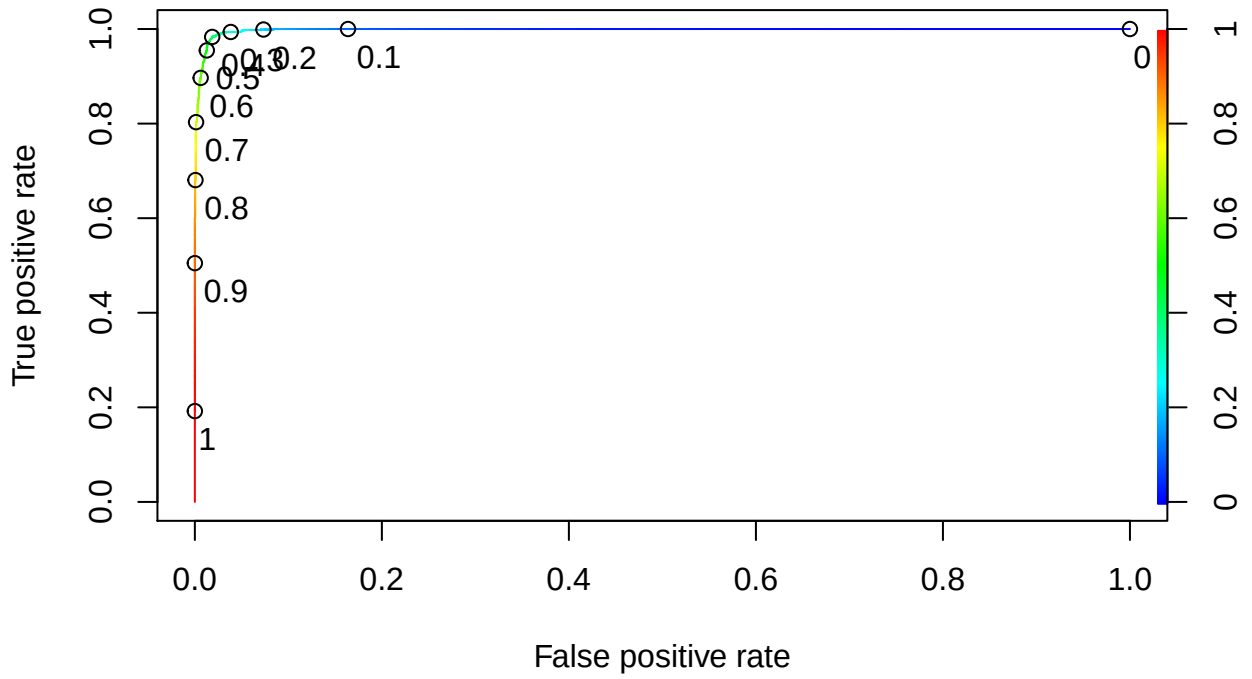
```
##
##      FALSE TRUE
##   0  3013   39
##   1    44  914
```

```
(3013+914)/nrow(train)
```

```
## [1] 0.9793017
```

Similar trend is obvious by calculating AUC number:

```
predROCR = prediction(predRF.prob, train$spam)
ROCRperf=performance(predROCR, "tpr", "fpr")
plot(ROCRperf, colorize=T, print.cutoffs.at=seq(0,1,0.1), text.adj=c(-0.2,1.7))
```




```
AUC = as.numeric(performance(predROCR, "auc")@y.values)
AUC
```

```
## [1] 0.9979116
```

We can conclude that Logistic Regression model gave best accuracy on the training set. However, we need to give them a real challange with the created test set. Similrly, we can calculate accuracy and AUC values for each model:

```
pred = predict(spamLog, newdata=test, type="response")
table(test$spam, pred>0.5)
```

```
##
##     FALSE TRUE
##   0  1257   51
##   1    34  376
```

```
(1257+376)/nrow(test)
```

```
## [1] 0.9505239
```

```
predROCR = prediction(pred, test$spam)
AUC = as.numeric(performance(predROCR, "auc")@y.values)
AUC
```

```
## [1] 0.9627517
```

```
predTestCART = predict(spamCART, newdata=test)[,2]
table(test$spam, predTestCART>0.5)
```

```
##
##     FALSE TRUE
##   0  1228   80
##   1    24  386
```

```
(1228+386)/nrow(test)
```

```
## [1] 0.9394645
```

```
predROCR = prediction(predTestCART , test$spam)
AUC = as.numeric(performance(predROCR, "auc")@y.values)
AUC
```

```
## [1] 0.963176
```

```
predTestRF = predict(spamRF, newdata=test, type="prob")[,2]
table(test$spam, predTestRF>0.5)
```

```
##
##     FALSE TRUE
##   0  1290   18
##   1    25  385
```

```
(1290+385)/nrow(test)
```

```
## [1] 0.9749709
```

```r
predROCR = prediction(predTestRF , test$spam)
AUC = as.numeric(performance(predROCR, "auc")@y.values)
AUC
```

```
## [1] 0.9975656
```

We can conlclude that both CART and Random Forest had very similar accuracies on the training and testing sets. However, logistic regression obtained nearly perfect accuracy and AUC on the training set and had far-from-perfect performance on the testing set. This is a clear indicator of overfitting in case of Logistic Regression, so for this problem Random Forest model seems to be an optimal solution.