Lab 7

Ransom notes keep falling

Alice Chang

The data

```
library(MASS)
library(gbm)
```

```
## Loaded gbm 2.1.5
```

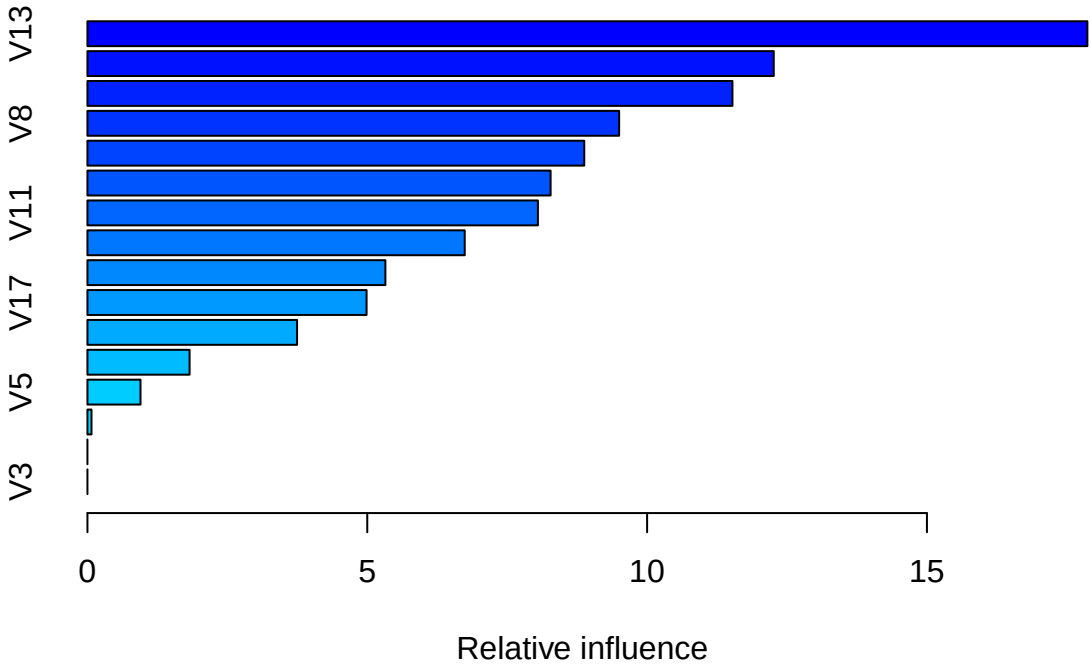
```
#load data
lettersdf <- read.csv("https://raw.githubusercontent.com/stat-learning/course-materials/master/data/let
                      header = FALSE)

#subset training data
set.seed(1)
train <- sample(1:nrow(lettersdf), nrow(lettersdf) * .75)
```

Building a boosted tree

```
set.seed(40)
boost.letters = gbm(V1 ~., data = lettersdf[train,], distribution = "multinomial", n.trees = 50, intera

summary(boost.letters)
```




```
##     var     rel.inf
## V13 V13 17.86698568
```

```
## V12 V12 12.26316006
## V14 V14 11.52503369
## V8   V8  9.50005008
## V10 V10  8.87710536
## V15 V15  8.27546181
## V11 V11  8.04893095
## V9   V9  6.74140462
## V16 V16  5.32378619
## V17 V17  4.98738525
## V7   V7  3.74533792
## V4   V4  1.82491867
## V5   V5  0.94813295
## V6   V6  0.07230675
## V2   V2  0.00000000
## V3   V3  0.00000000
```

V13 (the measure of the correlation of the vertical variance with the horizontal position) is the most important variable.

Assessing predictions

```
#Predict letters
yhat.boost = predict(boost.letters,newdata = lettersdf[-train,], n.trees = 50, type = "response")
pred_letters<- LETTERS[apply(yhat.boost, 1, which.max)]
pred_letters
```

```
##    [1] "T" "B" "K" "B" "E" "Q" "X" "X" "G" "W" "L" "Q" "H" "J" "R" "B" "W"
##   [18] "N" "Y" "D" "T" "P" "U" "N" "R" "E" "C" "A" "K" "Z" "M" "A" "H" "B"
##   [35] "V" "D" "B" "N" "S" "I" "M" "P" "O" "C" "Z" "O" "L" "C" "B" "X" "B"
##   [52] "D" "P" "Z" "S" "C" "M" "L" "F" "T" "R" "G" "V" "Z" "M" "A" "O" "H"
##   [69] "I" "B" "M" "V" "X" "V" "A" "P" "O" "D" "F" "B" "K" "U" "Y" "R" "Q"
##   [86] "B" "M" "D" "R" "G" "V" "X" "C" "J" "D" "D" "J" "I" "J" "M" "J" "Z"
##  [103] "N" "C" "Z" "W" "J" "M" "U" "B" "B" "N" "M" "B" "M" "D" "B" "S" "O"
##  [120] "D" "O" "N" "J" "S" "V" "B" "O" "Y" "X" "N" "E" "R" "V" "J" "A" "P"
##  [137] "O" "S" "N" "G" "T" "W" "F" "V" "B" "M" "M" "G" "B" "W" "K" "Y" "Q"
##  [154] "R" "D" "P" "X" "P" "H" "P" "D" "T" "J" "Q" "A" "S" "I" "Y" "F" "P"
##  [171] "G" "I" "Y" "E" "K" "Y" "X" "U" "O" "D" "X" "B" "A" "Y" "A" "Z" "P"
##  [188] "Q" "H" "T" "G" "L" "F" "Y" "S" "N" "G" "N" "B" "R" "G" "G" "S" "L"
##  [205] "G" "F" "R" "S" "I" "G" "K" "B" "K" "L" "T" "Y" "C" "Y" "S" "T" "S"
##  [222] "E" "L" "P" "N" "M" "S" "M" "D" "F" "T" "M" "Z" "O" "L" "E" "K" "N"
##  [239] "D" "R" "T" "F" "W" "Y" "Y" "N" "A" "F" "A" "F" "S" "T" "A" "G" "O"
##  [256] "Z" "J" "E" "A" "C" "B" "D" "G" "U" "S" "J" "G" "H" "O" "B" "B" "J"
##  [273] "T" "D" "U" "Z" "P" "D" "T" "F" "B" "Y" "V" "E" "E" "X" "Z" "Y" "P"
##  [290] "O" "X" "O" "G" "K" "X" "Z" "K" "I" "S" "C" "Y" "O" "T" "F" "S" "Q"
##  [307] "Y" "V" "B" "O" "C" "A" "T" "H" "C" "J" "M" "I" "K" "V" "M" "Y" "I"
##  [324] "C" "R" "A" "E" "C" "B" "D" "Z" "U" "K" "A" "Q" "P" "G" "A" "T" "Q"
##  [341] "Y" "M" "N" "B" "K" "D" "D" "A" "X" "V" "N" "X" "R" "N" "Y" "W" "D"
##  [358] "U" "S" "O" "Z" "L" "B" "U" "P" "R" "O" "I" "Q" "Q" "U" "K" "S" "T"
##  [375] "Z" "D" "C" "H" "X" "X" "P" "B" "Q" "G" "U" "J" "P" "I" "C" "I" "B"
##  [392] "M" "Z" "P" "N" "O" "F" "H" "D" "V" "K" "W" "N" "K" "Z" "A" "C" "A"
##  [409] "V" "H" "O" "A" "T" "G" "W" "Z" "W" "G" "N" "K" "P" "L" "K" "G" "X"
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##  [443] "U" "N" "E" "J" "K" "S" "D" "H" "Y" "W" "F" "U" "N" "X" "V" "G" "C"
##  [460] "V" "W" "B" "N" "N" "M" "Y" "W" "K" "O" "A" "Q" "E" "U" "O" "O" "N"
##  [477] "L" "H" "R" "G" "J" "K" "F" "G" "U" "D" "X" "I" "O" "P" "A" "K" "G"
```

```
##  [494] "K" "A" "T" "Q" "Y" "R" "F" "R" "Q" "F" "G" "Q" "D" "C" "L" "M" "W"
##  [511] "B" "C" "T" "C" "G" "B" "Q" "Y" "D" "R" "I" "D" "V" "B" "V" "C" "F"
##  [528] "A" "U" "J" "U" "S" "O" "R" "F" "O" "M" "Y" "M" "R" "R" "O" "A" "S"
##  [545] "Q" "G" "Z" "C" "F" "S" "M" "Y" "R" "C" "D" "Z" "X" "H" "U" "Q" "W"
##  [562] "W" "G" "G" "U" "A" "R" "M" "U" "C" "U" "P" "J" "Z" "M" "I" "J" "P"
##  [579] "F" "Z" "A" "J" "J" "B" "G" "B" "K" "L" "O" "D" "I" "M" "N" "B" "H"
##  [596] "O" "S" "W" "F" "B" "U" "N" "T" "L" "G" "E" "O" "D" "K" "Q" "D" "N"
##  [613] "Q" "J" "A" "M" "Q" "B" "M" "V" "Q" "Z" "R" "B" "Z" "T" "Y" "R" "R"
##  [630] "X" "C" "Q" "F" "B" "P" "G" "R" "N" "B" "J" "R" "O" "B" "R" "H" "Y"
##  [647] "A" "J" "Q" "W" "G" "T" "L" "K" "S" "C" "X" "A" "E" "M" "I" "M" "X"
##  [664] "F" "T" "M" "L" "Y" "P" "S" "C" "X" "E" "L" "T" "B" "K" "V" "S" "H"
##  [681] "O" "V" "J" "L" "D" "H" "O" "X" "X" "T" "C" "A" "O" "L" "N" "T" "Z"
##  [698] "N" "P" "I" "G" "F" "I" "F" "W" "Q" "T" "O" "K" "S" "X" "H" "G" "O"
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##  [732] "K" "A" "M" "B" "Q" "Q" "M" "F" "X" "N" "R" "R" "M" "X" "Q" "M" "C"
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##  [766] "Y" "I" "V" "U" "Q" "Y" "K" "F" "I" "Q" "N" "S" "V" "Y" "Z" "F" "R"
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##  [800] "R" "D" "C" "O" "D" "J" "B" "C" "V" "Y" "F" "Y" "N" "Y" "K" "B" "L"
##  [817] "O" "G" "C" "Z" "B" "H" "B" "J" "G" "S" "T" "V" "O" "Q" "H" "T" "R"
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##  [851] "N" "O" "V" "X" "O" "J" "K" "C" "O" "D" "C" "K" "A" "F" "X" "M" "W"
##  [868] "Q" "A" "T" "H" "N" "E" "M" "H" "T" "I" "X" "L" "W" "U" "Q" "F" "C"
##  [885] "S" "X" "S" "Z" "J" "W" "X" "I" "F" "V" "O" "M" "K" "J" "F" "S" "K"
##  [902] "T" "B" "U" "W" "C" "S" "L" "S" "A" "M" "S" "M" "X" "H" "R" "S" "F"
##  [919] "X" "X" "L" "O" "T" "N" "D" "O" "R" "O" "V" "N" "M" "K" "O" "B" "G"
##  [936] "K" "Y" "X" "W" "Y" "G" "T" "Z" "G" "P" "Q" "N" "M" "T" "B" "O" "I"
##  [953] "K" "Z" "A" "M" "I" "U" "O" "X" "B" "O" "S" "Q" "Y" "D" "U" "R" "R"
##  [970] "Z" "A" "V" "G" "B" "X" "J" "R" "Z" "W" "B" "C" "M" "R" "Y" "R" "S"
##  [987] "N" "G" "J" "G" "S" "F" "F" "Q" "K" "Q" "Z" "R" "W" "H" "D" "T" "J"
## [1004] "C" "J" "N" "G" "M" "Z" "N" "L" "B" "K" "J" "C" "P" "U" "J" "N" "B"
## [1021] "E" "P" "D" "X" "T" "K" "J" "J" "F" "A" "P" "O" "C" "Y" "S" "W" "D"
## [1038] "O" "A" "F" "F" "X" "L" "A" "D" "E" "T" "M" "Y" "G" "U" "I" "H" "G"
## [1055] "B" "A" "B" "R" "I" "P" "R" "K" "Y" "R" "B" "E" "J" "P" "A" "U" "C"
## [1072] "T" "A" "B" "Y" "A" "F" "O" "N" "L" "Z" "E" "N" "O" "X" "G" "T" "M"
## [1089] "D" "C" "Q" "B" "Y" "V" "Y" "T" "D" "L" "F" "U" "E" "R" "M" "V" "X"
## [1106] "U" "N" "Z" "I" "K" "F" "U" "R" "S" "F" "O" "R" "B" "N" "V" "Q" "K"
## [1123] "B" "R" "L" "S" "Y" "M" "B" "E" "H" "Y" "B" "X" "S" "B" "A" "B" "Q"
## [1140] "Z" "C" "W" "V" "H" "Q" "D" "G" "A" "G" "R" "L" "T" "C" "L" "X" "A"
## [1157] "T" "Z" "M" "U" "E" "U" "W" "M" "R" "V" "B" "T" "O" "P" "T" "W" "R"
## [1174] "P" "X" "R" "K" "D" "R" "L" "R" "R" "T" "J" "U" "B" "Z" "Y" "I" "Q"
## [1191] "A" "T" "D" "Q" "A" "J" "B" "K" "M" "U" "L" "P" "F" "Y" "Y" "G" "C"
## [1208] "A" "F" "O" "D" "M" "Q" "O" "F" "D" "F" "M" "A" "J" "R" "V" "W" "F"
## [1225] "E" "V" "M" "I" "N" "M" "I" "O" "S" "B" "B" "B" "O" "S" "D" "K" "J"
## [1242] "T" "N" "Y" "M" "F" "C" "H" "K" "Q" "Y" "S" "E" "I" "F" "O" "H" "L"
## [1259] "U" "M" "S" "N" "E" "V" "N" "E" "Q" "J" "A" "D" "G" "U" "S" "U" "G"
## [1276] "Q" "Z" "Z" "M" "D" "I" "U" "D" "Y" "D" "T" "K" "B" "T" "J" "A" "S"
## [1293] "P" "M" "I" "B" "C" "X" "G" "B" "C" "S" "L" "W" "K" "X" "A" "T" "D"
## [1310] "V" "R" "Z" "Y" "P" "X" "D" "R" "X" "S" "U" "M" "N" "T" "O" "T" "G"
## [1327] "W" "B" "W" "N" "B" "G" "Q" "M" "Z" "U" "T" "K" "O" "U" "M" "M" "G"
## [1344] "G" "X" "X" "T" "V" "X" "L" "H" "F" "I" "H" "G" "W" "A" "S" "D" "L"
## [1361] "W" "A" "P" "Y" "K" "M" "M" "N" "M" "Z" "B" "E" "Z" "W" "O" "K" "J"
## [1378] "B" "U" "X" "F" "C" "S" "B" "X" "U" "W" "T" "A" "C" "Q" "Q" "N" "K"
## [1395] "B" "S" "V" "B" "P" "U" "O" "S" "F" "N" "B" "R" "O" "T" "R" "X" "X"
```

```
## [1412] "L" "N" "V" "S" "K" "S" "T" "L" "D" "C" "X" "R" "Y" "Q" "C" "S" "I"
## [1429] "Y" "A" "F" "X" "S" "W" "C" "D" "U" "M" "S" "Y" "O" "B" "C" "A" "U"
## [1446] "M" "O" "S" "D" "S" "C" "N" "D" "X" "B" "O" "S" "S" "A" "Z" "M" "J"
## [1463] "I" "O" "X" "M" "N" "B" "X" "R" "P" "P" "M" "O" "T" "D" "B" "G" "B"
## [1480] "M" "X" "Z" "R" "I" "S" "T" "N" "M" "B" "V" "I" "R" "G" "W" "R" "F"
## [1497] "D" "S" "I" "Q" "U" "Q" "K" "R" "L" "X" "W" "P" "Y" "K" "D" "S" "G"
## [1514] "O" "V" "V" "O" "E" "D" "H" "Q" "E" "X" "R" "J" "N" "V" "Z" "A" "H"
## [1531] "I" "F" "S" "E" "K" "B" "K" "T" "L" "O" "E" "M" "O" "Q" "X" "R" "V"
## [1548] "G" "R" "S" "T" "K" "M" "Z" "C" "A" "M" "T" "C" "X" "W" "B" "M" "U"
## [1565] "N" "U" "M" "W" "M" "D" "Q" "K" "B" "L" "L" "S" "O" "I" "D" "U" "Z"
## [1582] "J" "T" "A" "F" "D" "Z" "F" "W" "X" "Y" "K" "R" "L" "K" "Z" "U" "O"
## [1599] "X" "K" "U" "L" "B" "U" "C" "Q" "I" "Q" "I" "B" "O" "V" "W" "P" "E"
## [1616] "U" "P" "V" "G" "U" "J" "L" "D" "A" "C" "E" "Y" "F" "E" "O" "E" "P"
## [1633] "N" "Y" "S" "Z" "P" "L" "V" "M" "F" "L" "S" "V" "D" "C" "V" "R" "K"
## [1650] "R" "Q" "N" "T" "A" "F" "J" "U" "C" "B" "B" "D" "J" "O" "R" "C" "D"
## [1667] "E" "O" "S" "J" "X" "A" "W" "D" "Y" "N" "Y" "H" "Y" "I" "K" "I" "Y"
## [1684] "X" "U" "R" "W" "Q" "M" "O" "X" "F" "H" "C" "S" "D" "Q" "U" "J" "M"
## [1701] "D" "G" "L" "X" "D" "N" "O" "B" "G" "S" "R" "R" "S" "M" "W" "H" "Q"
## [1718] "G" "J" "Q" "H" "N" "Q" "V" "C" "D" "X" "K" "R" "F" "K" "Y" "Y" "T"
## [1735] "T" "X" "X" "O" "Q" "D" "A" "K" "T" "D" "R" "Z" "F" "L" "O" "L" "C"
## [1752] "C" "R" "R" "Z" "B" "O" "H" "Y" "O" "R" "O" "T" "Y" "N" "K" "S" "L"
## [1769] "N" "X" "V" "Q" "A" "Q" "K" "G" "M" "M" "B" "R" "O" "N" "R" "V" "Y"
## [1786] "S" "Y" "I" "W" "C" "D" "Y" "W" "A" "Z" "M" "T" "G" "O" "K" "F" "A"
## [1803] "H" "U" "R" "I" "X" "R" "T" "I" "K" "M" "D" "B" "E" "C" "I" "O" "O"
## [1820] "K" "J" "P" "U" "H" "E" "F" "V" "I" "T" "O" "H" "V" "S" "G" "I" "D"
## [1837] "S" "S" "L" "G" "P" "T" "W" "N" "R" "Q" "W" "B" "C" "S" "O" "V" "R"
## [1854] "P" "J" "D" "J" "V" "B" "J" "S" "B" "G" "Z" "J" "R" "Q" "N" "X" "F"
## [1871] "P" "Q" "U" "F" "T" "K" "V" "M" "Q" "M" "A" "Y" "A" "E" "C" "C" "M"
## [1888] "N" "G" "H" "A" "K" "R" "X" "B" "Y" "R" "C" "G" "P" "U" "T" "H" "O"
## [1905] "E" "D" "P" "O" "R" "Y" "G" "R" "P" "F" "E" "N" "O" "N" "N" "H" "K"
## [1922] "Z" "Y" "R" "P" "E" "K" "S" "B" "L" "S" "P" "D" "R" "U" "S" "Z" "D"
## [1939] "Z" "X" "M" "U" "N" "F" "K" "L" "V" "Z" "K" "I" "L" "C" "U" "J" "G"
## [1956] "X" "T" "K" "P" "Z" "O" "W" "O" "G" "S" "O" "K" "C" "F" "F" "N" "X"
## [1973] "H" "M" "L" "P" "N" "E" "I" "W" "P" "S" "X" "H" "X" "G" "U" "Z" "F"
## [1990] "N" "N" "D" "B" "S" "A" "B" "V" "D" "N" "O" "W" "Q" "O" "K" "W" "U"
## [2007] "B" "A" "R" "X" "L" "E" "C" "B" "E" "U" "T" "Y" "B" "N" "D" "I" "O"
## [2024] "T" "L" "A" "P" "P" "W" "Q" "V" "R" "C" "P" "T" "R" "A" "J" "X" "L"
## [2041] "A" "M" "T" "W" "G" "P" "Z" "B" "W" "L" "P" "D" "Z" "B" "H" "Q" "R"
## [2058] "Y" "J" "P" "F" "D" "R" "K" "P" "N" "B" "X" "N" "X" "O" "U" "P" "C"
## [2075] "B" "Z" "R" "X" "X" "H" "L" "E" "W" "P" "N" "Z" "Z" "C" "Y" "R" "M"
## [2092] "B" "R" "M" "M" "T" "C" "X" "P" "B" "Q" "D" "D" "V" "U" "U" "X" "M"
## [2109] "S" "S" "D" "L" "I" "P" "M" "P" "R" "O" "X" "Z" "M" "V" "W" "F" "U"
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## [2160] "N" "O" "Z" "R" "C" "S" "N" "D" "W" "G" "J" "U" "Z" "Z" "B" "X" "W"
## [2177] "I" "O" "Q" "F" "V" "U" "P" "A" "Q" "M" "Y" "C" "D" "Y" "O" "H" "N"
## [2194] "N" "D" "B" "W" "C" "P" "F" "B" "L" "P" "M" "L" "F" "F" "Z" "X" "U"
## [2211] "K" "M" "D" "Y" "B" "J" "V" "B" "O" "M" "T" "M" "D" "X" "C" "I" "K"
## [2228] "O" "R" "P" "M" "R" "H" "A" "P" "O" "O" "V" "N" "B" "N" "A" "Y" "V"
## [2245] "A" "I" "T" "N" "Q" "U" "O" "D" "Q" "A" "I" "M" "Z" "R" "T" "R" "B"
## [2262] "A" "X" "F" "Y" "O" "W" "I" "R" "X" "X" "Y" "U" "F" "D" "C" "Q" "I"
## [2279] "T" "D" "N" "F" "B" "U" "B" "K" "Z" "S" "I" "U" "N" "M" "B" "U" "D"
## [2296] "I" "M" "Z" "Z" "X" "C" "P" "W" "O" "A" "B" "X" "N" "W" "Z" "N" "K"
## [2313] "Q" "Z" "M" "T" "O" "L" "Z" "F" "I" "M" "B" "C" "Q" "C" "A" "V" "D"
```

```
## [2330] "D" "R" "D" "F" "Q" "T" "Z" "N" "C" "N" "O" "N" "G" "R" "C" "T" "R"
## [2347] "C" "G" "A" "I" "S" "B" "Z" "F" "O" "I" "O" "S" "V" "L" "W" "M" "F"
## [2364] "V" "P" "L" "C" "Y" "O" "S" "I" "T" "P" "R" "W" "N" "X" "M" "A" "O"
## [2381] "C" "I" "V" "G" "W" "O" "Q" "X" "V" "Q" "V" "N" "U" "L" "O" "E" "F"
## [2398] "I" "G" "T" "D" "W" "M" "O" "K" "C" "O" "G" "K" "I" "C" "O" "W" "G"
## [2415] "Z" "B" "H" "F" "M" "V" "W" "X" "C" "D" "V" "R" "K" "M" "H" "S" "W"
## [2432] "S" "E" "A" "M" "Q" "B" "W" "L" "O" "L" "Q" "W" "P" "O" "B" "Z" "C"
## [2449] "R" "J" "U" "Q" "W" "P" "L" "M" "B" "I" "C" "E" "R" "Q" "R" "Y" "O"
## [2466] "V" "A" "U" "C" "K" "K" "U" "J" "B" "C" "E" "S" "D" "H" "I" "I" "O"
## [2483] "D" "N" "N" "I" "S" "O" "L" "C" "I" "J" "D" "M" "F" "X" "E" "D" "D"
## [2500] "Q" "B" "M" "R" "V" "M" "B" "M" "C" "Z" "S" "S" "Q" "Q" "F" "U" "A"
## [2517] "U" "V" "S" "H" "N" "K" "T" "O" "X" "A" "I" "X" "T" "R" "B" "W" "C"
## [2534] "V" "J" "D" "L" "L" "R" "U" "F" "M" "C" "M" "Y" "N" "V" "M" "G" "Q"
## [2551] "Q" "T" "M" "Q" "N" "H" "A" "O" "U" "C" "K" "X" "F" "E" "J" "M" "N"
## [2568] "Z" "O" "M" "X" "D" "J" "Y" "B" "G" "N" "I" "G" "B" "T" "L" "Q" "V"
## [2585] "R" "Q" "J" "D" "E" "J" "B" "W" "R" "S" "V" "L" "N" "E" "D" "Y" "R"
## [2602] "G" "O" "C" "V" "G" "L" "V" "W" "L" "R" "M" "U" "O" "C" "V" "X" "T"
## [2619] "W" "P" "B" "T" "A" "R" "G" "Q" "N" "M" "L" "O" "W" "S" "E" "M" "C"
## [2636] "T" "R" "U" "X" "G" "A" "T" "A" "O" "D" "K" "S" "R" "N" "C" "Q" "S"
## [2653] "A" "H" "M" "B" "T" "B" "F" "X" "R" "O" "N" "W" "W" "K" "R" "R" "O"
## [2670] "N" "O" "O" "P" "O" "B" "C" "R" "V" "F" "N" "L" "D" "Y" "L" "K" "X"
## [2687] "R" "M" "R" "B" "A" "X" "A" "H" "P" "W" "L" "L" "O" "Y" "S" "V" "W"
## [2704] "F" "X" "V" "O" "Y" "X" "K" "M" "D" "S" "C" "C" "E" "D" "R" "I" "J"
## [2721] "G" "N" "P" "N" "O" "G" "S" "W" "P" "M" "X" "Y" "D" "D" "E" "M" "W"
## [2738] "N" "G" "D" "L" "U" "E" "O" "R" "A" "Q" "M" "N" "D" "C" "X" "A" "X"
## [2755] "C" "I" "Y" "W" "Z" "P" "O" "O" "D" "K" "B" "M" "K" "O" "B" "P" "D"
## [2772] "L" "D" "A" "N" "Z" "A" "O" "V" "M" "M" "K" "N" "F" "X" "H" "H" "X"
## [2789] "T" "I" "J" "P" "W" "M" "X" "Q" "J" "D" "S" "O" "O" "Q" "I" "L" "A"
## [2806] "T" "P" "M" "K" "X" "E" "D" "J" "W" "K" "T" "B" "X" "N" "O" "R" "O"
## [2823] "X" "P" "D" "G" "O" "O" "S" "M" "Q" "V" "E" "R" "V" "R" "R" "X" "X"
## [2840] "D" "S" "E" "C" "D" "W" "M" "E" "M" "E" "C" "N" "B" "W" "S" "V" "R"
## [2857] "M" "G" "G" "R" "T" "P" "K" "B" "N" "Q" "J" "V" "M" "M" "Y" "T" "I"
## [2874] "O" "M" "F" "T" "A" "W" "E" "F" "D" "R" "K" "R" "K" "Z" "K" "K" "S"
## [2891] "B" "H" "N" "Z" "C" "P" "E" "Z" "X" "J" "U" "R" "V" "Y" "B" "P" "C"
## [2908] "S" "A" "C" "A" "W" "L" "R" "R" "D" "S" "S" "A" "U" "U" "Y" "H" "Z"
## [2925] "P" "O" "J" "B" "R" "X" "U" "N" "X" "U" "X" "S" "B" "N" "A" "E" "I"
## [2942] "M" "N" "A" "F" "Y" "Y" "R" "U" "N" "E" "W" "I" "Y" "G" "R" "V" "X"
## [2959] "O" "B" "T" "U" "M" "Q" "W" "M" "L" "R" "N" "R" "R" "X" "V" "W" "Q"
## [2976] "R" "K" "B" "Z" "T" "L" "L" "W" "W" "B" "O" "V" "J" "B" "K" "V" "S"
## [2993] "S" "N" "T" "B" "G" "P" "E" "W" "D" "C" "P" "Z" "U" "C" "A" "R" "V"
## [3010] "S" "O" "X" "W" "W" "Q" "G" "J" "L" "B" "A" "R" "I" "Q" "V" "A" "L"
## [3027] "J" "G" "S" "I" "F" "R" "O" "V" "P" "M" "D" "S" "B" "J" "B" "Y" "H"
## [3044] "N" "L" "C" "N" "X" "D" "F" "D" "Y" "G" "L" "G" "K" "D" "P" "W" "Q"
## [3061] "F" "A" "O" "E" "O" "Y" "D" "D" "O" "X" "D" "I" "V" "G" "C" "D" "P"
## [3078] "C" "M" "G" "S" "D" "S" "C" "R" "N" "M" "D" "M" "E" "G" "L" "V" "D"
## [3095] "Q" "S" "V" "Z" "R" "U" "A" "U" "F" "W" "G" "B" "X" "X" "V" "I" "Q"
## [3112] "T" "A" "L" "O" "T" "M" "M" "T" "J" "S" "X" "N" "B" "Q" "E" "G" "C"
## [3129] "Y" "Y" "H" "N" "Z" "J" "M" "Z" "S" "S" "D" "R" "Q" "O" "D" "L" "H"
## [3146] "C" "I" "B" "W" "W" "X" "M" "A" "O" "O" "Y" "I" "G" "U" "M" "R" "S"
## [3163] "J" "K" "E" "E" "H" "O" "O" "N" "S" "B" "P" "Z" "P" "T" "Q" "W" "B"
## [3180] "U" "C" "R" "O" "P" "P" "N" "P" "L" "R" "X" "P" "M" "K" "Q" "Z" "R"
## [3197] "O" "U" "I" "O" "B" "Z" "K" "C" "A" "W" "R" "U" "O" "S" "F" "A" "Y"
## [3214] "N" "D" "L" "L" "R" "F" "O" "P" "M" "X" "K" "Q" "P" "O" "U" "K" "G"
## [3231] "C" "X" "S" "V" "D" "E" "V" "A" "A" "O" "O" "K" "U" "S" "V" "F" "F"
```

```
## [3248] "J" "M" "B" "J" "K" "T" "A" "I" "D" "W" "N" "T" "X" "S" "C" "J" "N"
## [3265] "B" "Y" "P" "Z" "S" "Y" "R" "W" "M" "B" "F" "N" "F" "O" "B" "J" "N"
## [3282] "A" "L" "I" "B" "B" "A" "U" "T" "U" "Z" "W" "D" "K" "H" "L" "W" "J"
## [3299] "E" "G" "B" "O" "M" "R" "M" "M" "P" "D" "G" "H" "W" "E" "J" "Y" "W"
## [3316] "Z" "I" "M" "R" "Z" "A" "I" "Y" "Y" "K" "V" "O" "E" "R" "O" "P" "Q"
## [3333] "T" "B" "N" "J" "D" "E" "X" "X" "J" "U" "E" "S" "V" "P" "I" "C" "T"
## [3350] "E" "P" "L" "U" "Q" "G" "D" "A" "V" "A" "O" "M" "U" "Q" "E" "I" "V"
## [3367] "W" "T" "S" "E" "K" "Y" "F" "B" "I" "T" "M" "X" "F" "A" "Y" "B" "V"
## [3384] "B" "O" "J" "K" "C" "D" "P" "B" "F" "K" "P" "H" "V" "F" "C" "B" "Z"
## [3401] "L" "K" "V" "W" "Y" "U" "X" "R" "P" "C" "Z" "T" "C" "R" "J" "M" "N"
## [3418] "S" "E" "I" "Y" "S" "L" "O" "I" "K" "C" "F" "G" "P" "N" "N" "J" "W"
## [3435] "D" "L" "D" "L" "F" "P" "O" "P" "Q" "B" "G" "K" "H" "B" "R" "Q" "R"
## [3452] "P" "D" "L" "O" "I" "P" "O" "A" "V" "M" "N" "J" "J" "K" "F" "S" "Z"
## [3469] "X" "S" "P" "O" "E" "X" "D" "Z" "X" "F" "U" "K" "F" "K" "P" "Y" "O"
## [3486] "U" "G" "I" "H" "N" "S" "I" "C" "C" "M" "Y" "O" "K" "I" "B" "I" "J"
## [3503] "V" "H" "O" "D" "B" "D" "K" "D" "O" "U" "H" "F" "W" "B" "X" "J" "I"
## [3520] "Q" "V" "S" "Q" "C" "Y" "D" "M" "S" "B" "C" "Q" "O" "T" "F" "E" "F"
## [3537] "K" "V" "B" "L" "X" "S" "P" "Y" "L" "O" "Y" "D" "U" "F" "X" "K" "X"
## [3554] "T" "L" "L" "L" "L" "F" "X" "Z" "K" "C" "Z" "U" "G" "Z" "M" "T" "R"
## [3571] "L" "C" "Q" "R" "R" "B" "Q" "W" "A" "B" "S" "Y" "C" "P" "W" "P" "Q"
## [3588] "U" "O" "O" "T" "X" "D" "W" "V" "D" "O" "Y" "M" "Q" "Q" "T" "Z" "G"
## [3605] "V" "D" "R" "A" "M" "P" "J" "Q" "W" "O" "E" "C" "Q" "D" "D" "P" "Y"
## [3622] "R" "Q" "O" "W" "L" "W" "R" "M" "D" "H" "C" "A" "N" "O" "U" "O" "H"
## [3639] "M" "R" "P" "K" "G" "R" "F" "U" "A" "W" "X" "Z" "O" "N" "M" "U" "V"
## [3656] "G" "M" "B" "G" "W" "A" "S" "T" "L" "L" "P" "Z" "L" "Z" "W" "J" "R"
## [3673] "T" "M" "A" "F" "B" "A" "F" "R" "F" "R" "A" "R" "G" "N" "D" "S" "R"
## [3690] "O" "J" "N" "B" "A" "O" "T" "H" "U" "N" "F" "F" "N" "V" "V" "F" "V"
## [3707] "I" "W" "M" "Z" "P" "O" "V" "F" "A" "B" "P" "D" "O" "F" "A" "I" "N"
## [3724] "M" "A" "L" "I" "B" "Y" "R" "L" "W" "O" "Z" "X" "Y" "R" "N" "F" "R"
## [3741] "V" "Y" "I" "A" "O" "P" "N" "M" "K" "T" "N" "I" "M" "N" "N" "B" "G"
## [3758] "B" "U" "D" "U" "R" "O" "E" "T" "B" "A" "R" "M" "W" "F" "G" "Z" "A"
## [3775] "A" "P" "D" "D" "B" "M" "Q" "S" "Z" "M" "F" "H" "Z" "M" "M" "F" "E"
## [3792] "V" "L" "R" "G" "W" "I" "B" "J" "A" "W" "G" "M" "B" "T" "L" "Y" "O"
## [3809] "N" "S" "U" "D" "K" "D" "H" "G" "C" "I" "S" "N" "G" "W" "A" "W" "C"
## [3826] "I" "S" "W" "M" "L" "N" "F" "D" "A" "U" "W" "U" "A" "G" "P" "I" "L"
## [3843] "D" "Z" "Z" "N" "Z" "C" "O" "A" "Y" "L" "W" "N" "C" "G" "G" "J" "B"
## [3860] "J" "M" "G" "Y" "A" "B" "N" "L" "O" "M" "U" "M" "O" "T" "L" "O" "A"
## [3877] "C" "N" "K" "Y" "H" "B" "L" "Q" "Y" "I" "W" "P" "D" "N" "Z" "M" "Z"
## [3894] "W" "I" "W" "N" "K" "R" "J" "U" "O" "X" "U" "Q" "B" "Y" "O" "P" "G"
## [3911] "R" "P" "F" "U" "L" "L" "K" "Z" "W" "T" "G" "E" "V" "O" "Z" "R" "J"
## [3928] "K" "R" "U" "B" "L" "C" "N" "M" "X" "J" "Y" "B" "A" "X" "R" "B" "K"
## [3945] "Y" "U" "R" "B" "G" "M" "F" "S" "Q" "L" "U" "O" "R" "A" "Q" "I" "E"
## [3962] "K" "U" "J" "X" "P" "V" "F" "U" "G" "G" "Z" "N" "S" "A" "B" "H" "K"
## [3979] "S" "I" "A" "E" "O" "A" "W" "D" "X" "Q" "E" "D" "T" "Y" "W" "N" "R"
## [3996] "Z" "P" "B" "X" "O" "P" "E" "D" "R" "D" "T" "W" "I" "Z" "F" "M" "N"
## [4013] "Y" "G" "L" "Q" "R" "N" "D" "C" "B" "O" "R" "H" "C" "A" "N" "H" "E"
## [4030] "B" "O" "O" "W" "Q" "H" "T" "I" "D" "Q" "G" "M" "Y" "S" "A" "I" "X"
## [4047] "R" "I" "W" "X" "J" "P" "G" "G" "L" "V" "U" "K" "U" "W" "T" "P" "P"
## [4064] "U" "I" "B" "U" "E" "A" "Y" "S" "K" "O" "K" "G" "E" "L" "J" "O" "J"
## [4081] "L" "B" "L" "G" "O" "V" "X" "I" "J" "N" "B" "S" "K" "P" "K" "K" "Q"
## [4098] "N" "Y" "U" "D" "O" "C" "D" "D" "H" "H" "S" "K" "M" "N" "Z" "W" "Y"
## [4115] "J" "V" "N" "R" "T" "M" "W" "F" "S" "B" "D" "O" "N" "Z" "B" "A" "N"
## [4132] "X" "F" "L" "B" "W" "Q" "S" "R" "L" "F" "Z" "J" "C" "T" "E" "R" "D"
## [4149] "F" "X" "G" "K" "A" "R" "N" "B" "N" "I" "B" "W" "D" "E" "M" "K" "L"
```

```
## [4166] "X" "Z" "N" "H" "C" "A" "D" "I" "D" "J" "O" "K" "A" "Y" "L" "I" "N"
## [4183] "L" "W" "Z" "M" "O" "X" "F" "H" "V" "M" "O" "Z" "U" "T" "D" "D" "C"
## [4200] "K" "N" "A" "K" "M" "V" "D" "O" "D" "Y" "I" "B" "P" "F" "E" "O" "S"
## [4217] "W" "D" "L" "D" "P" "E" "U" "R" "B" "R" "H" "M" "O" "I" "M" "O" "J"
## [4234] "A" "B" "C" "J" "B" "J" "V" "Z" "B" "Y" "D" "K" "Y" "X" "F" "R" "S"
## [4251] "B" "U" "T" "K" "B" "B" "E" "A" "A" "C" "B" "I" "M" "T" "W" "Q" "B"
## [4268] "G" "O" "R" "Y" "W" "C" "V" "R" "O" "Z" "R" "K" "N" "B" "V" "X" "J"
## [4285] "L" "N" "Q" "A" "R" "V" "Q" "Y" "P" "X" "S" "L" "J" "D" "Q" "V" "Z"
## [4302] "Q" "B" "Q" "Q" "U" "A" "Z" "X" "T" "J" "T" "Y" "J" "M" "D" "R" "W"
## [4319] "V" "A" "X" "A" "Y" "T" "B" "B" "U" "D" "V" "B" "J" "F" "L" "I" "D"
## [4336] "I" "I" "R" "I" "X" "F" "O" "Q" "F" "X" "X" "S" "N" "Z" "O" "Y" "U"
## [4353] "G" "R" "R" "F" "P" "Q" "E" "M" "H" "V" "V" "P" "Y" "K" "B" "C" "O"
## [4370] "Y" "W" "S" "Q" "Z" "P" "P" "A" "R" "F" "X" "M" "L" "Z" "O" "N" "M"
## [4387] "C" "S" "E" "M" "M" "O" "B" "M" "O" "X" "X" "Z" "A" "C" "E" "K" "L"
## [4404] "Y" "P" "P" "Z" "S" "V" "X" "R" "Z" "K" "W" "W" "X" "F" "Q" "F" "T"
## [4421] "K" "X" "D" "I" "L" "B" "K" "R" "F" "M" "L" "M" "U" "R" "U" "U" "Q"
## [4438] "K" "F" "Q" "I" "B" "V" "V" "B" "N" "B" "X" "S" "A" "S" "Q" "Q" "J"
## [4455] "G" "T" "S" "A" "C" "B" "G" "Q" "Z" "T" "W" "I" "I" "P" "S" "H" "N"
## [4472] "H" "F" "O" "W" "I" "A" "A" "D" "I" "Q" "S" "G" "W" "D" "W" "C" "Q"
## [4489] "K" "I" "R" "O" "A" "G" "J" "U" "I" "T" "B" "W" "D" "A" "H" "F" "U"
## [4506] "M" "Q" "D" "F" "Z" "W" "T" "L" "X" "G" "X" "J" "H" "K" "C" "M" "W"
## [4523] "D" "N" "D" "C" "Z" "R" "A" "I" "K" "P" "Y" "B" "R" "K" "D" "R" "Q"
## [4540] "K" "I" "R" "I" "Q" "W" "U" "X" "G" "M" "G" "B" "F" "R" "D" "D" "J"
## [4557] "Z" "J" "K" "Z" "O" "W" "T" "D" "P" "H" "Y" "R" "W" "Y" "P" "U" "S"
## [4574] "N" "B" "F" "C" "V" "C" "J" "Z" "G" "Z" "S" "E" "N" "N" "B" "Z" "M"
## [4591] "E" "A" "J" "A" "K" "Z" "I" "S" "T" "N" "L" "M" "O" "L" "Y" "J" "K"
## [4608] "T" "T" "V" "R" "J" "R" "C" "X" "R" "C" "A" "M" "Q" "T" "G" "L" "A"
## [4625] "M" "A" "Z" "U" "N" "B" "L" "A" "I" "O" "D" "T" "Z" "M" "G" "C" "W"
## [4642] "U" "M" "M" "B" "W" "X" "V" "L" "S" "F" "B" "K" "Z" "N" "B" "B" "X"
## [4659] "V" "N" "Z" "C" "X" "I" "W" "O" "A" "K" "D" "O" "G" "N" "M" "Z" "W"
## [4676] "S" "M" "F" "X" "Y" "Q" "W" "S" "F" "G" "F" "I" "X" "O" "X" "X" "A"
## [4693] "I" "B" "O" "R" "I" "K" "S" "Y" "T" "D" "T" "X" "C" "I" "F" "N" "V"
## [4710] "I" "X" "Q" "B" "Y" "P" "U" "A" "O" "C" "S" "H" "Z" "Q" "D" "Z" "D"
## [4727] "I" "C" "N" "C" "R" "R" "C" "O" "A" "V" "G" "N" "W" "B" "X" "B" "V"
## [4744] "J" "Z" "K" "U" "S" "C" "J" "O" "B" "V" "E" "M" "G" "X" "B" "K" "G"
## [4761] "B" "Y" "H" "C" "M" "Z" "M" "J" "L" "A" "K" "A" "Y" "G" "K" "N" "Z"
## [4778] "M" "I" "K" "G" "R" "Q" "N" "D" "J" "W" "W" "V" "C" "O" "A" "M" "P"
## [4795] "S" "M" "Q" "A" "D" "J" "T" "J" "D" "D" "P" "N" "F" "D" "W" "R" "D"
## [4812] "X" "I" "G" "X" "D" "H" "C" "O" "X" "K" "R" "R" "G" "B" "W" "D" "Y"
## [4829] "D" "F" "T" "N" "E" "W" "A" "Y" "S" "R" "R" "F" "M" "W" "Y" "M" "F"
## [4846] "N" "D" "K" "Z" "L" "M" "U" "B" "G" "I" "G" "L" "G" "U" "R" "O" "B"
## [4863] "U" "V" "T" "J" "I" "F" "O" "P" "N" "W" "P" "T" "N" "J" "B" "F" "T"
## [4880] "O" "L" "P" "Z" "J" "D" "W" "F" "Y" "V" "K" "D" "B" "D" "Y" "R" "B"
## [4897] "S" "N" "A" "G" "F" "J" "F" "C" "B" "V" "S" "Z" "R" "T" "B" "R" "M"
## [4914] "T" "V" "A" "C" "P" "D" "Y" "R" "W" "E" "R" "G" "X" "M" "C" "E" "B"
## [4931] "D" "M" "F" "L" "J" "Q" "D" "C" "N" "L" "Q" "X" "J" "O" "S" "T" "M"
## [4948] "T" "B" "J" "R" "E" "R" "G" "I" "G" "F" "J" "I" "G" "W" "P" "J" "O"
## [4965] "D" "T" "Y" "M" "E" "J" "R" "M" "Z" "Y" "E" "X" "M" "Y" "Q" "J" "E"
## [4982] "Y" "Y" "N" "G" "X" "X" "O" "J" "L" "D" "K" "W" "S" "M" "O" "X" "X"
## [4999] "T" "A"
```

```
#Build confusion matrix
conf_letters <- table(pred_letters, lettersdf[-train,]$V1)
conf_letters
```

```
##
## pred_letters   A   B   C   D   E   F   G   H   I   J   K   L   M   N   O
##            A 174   0   0   0   0   0   1   0   1   0   2  11   5   0   0
##            B   0 127   0  25   5  13   3  11  14  18   2   3   2   5   1
##            C   2   0 123   0  24   0  16   0   1   3   6   5   1   3   1
##            D   0  19   0 133   0  15   6  11   5   6   4   0   1   3  10
##            E   0   0  10   1  71   0   3   0   0   1   6   1   0   0   0
##            F   0   0   3   1   0 121   0   1   2   3   0   0   0   1   0
##            G   1   1   8   0  18   7 111   3   1   0   4   8   0   0   5
##            H   0   0   0   2   0   0   1  80   0   0   3   0   1   0   0
##            I   0   0   0   0   0   4   0   0 147   1   0   0   0   0   0
##            J   5   0   0   5   0   2   0   0   7 132   0   0   0   1   0
##            K   1   1  23   1  11   0   4  14   0   1 107   5   4   0   1
##            L   2   0   1   0   0   0   2   0   0   0   1 145   0   0   4
##            M   3   8   0   1   1   1   0   4   1   2   7   0 174   8   0
##            N   0   2   0   3   0   0   0   5   0   1   5   0  10 160   1
##            O   5   3   8   7   0   0   2  27   0   4   0   0   5   7 146
##            P   0   0   0   7   0  13   0   0   3   3   0   0   0   9   0
##            Q   1   1   1   0  12   0  18   6   1   3   0   2   1   0   5
##            R   0  13   0   9   6   4  13   9   2   7  18   2   0   2   2
##            S   2   5   3   6   7   2   3   3   2   6   0   3   1   0   0
##            T   0   0   0   2   2   6   0   2   0   0   0   0   0   0   0
##            U   0   0   2   0   1   1   0  12   0   0   0   0   0   1   2
##            V   0   0   0   0   0   0   1   0   0   0   0   0   0   1   0
##            W   0   1   2   0   0   0   6   4   0   0   2   0   2   2  10
##            X   4   3   0   0  27   2   0   2   6   0  10   1   0   0   0
##            Y   3   0   0   0   2   5   0   0   0   0   2   8   0   5   0
##            Z   1   0   2   0  19   1   4   0   0   0   0   0   0   0   0
##
## pred_letters   P   Q   R   S   T   U   V   W   X   Y   Z
##            A   0   1   0   8   0   0   0   0   0   0   1
##            B   7   3  16  10   2   1   0   0   7   1   2
##            C   0   5   0   0   0   1   0   0   0   0   0
##            D  11   0   8   6   0   1   0   0   3   4   2
##            E   0   2   5   3   8   3   0   0   1   0   6
##            F  21   0   0   2  16   0   5   4   0   5   0
##            G   3  11   0   0   0   1   0   0   0   0   1
##            H   0   0   0   2   0   0   0   0  12   0   0
##            I   1   0   0   4   5   0   0   0   0   2   0
##            J   2   2   0   1   0   0   0   0   0   0   1
##            K   0   0   2   1   2   3   0   0   9   0   1
##            L   0  11   0   0   0   0   0   0   0   0   1
##            M   0   2  11   0   0  14   2  13   1   1   0
##            N   0   0   2   0   2  14   6   7   0   0   0
##            O  10  17   2  10   3   6   1   4   4   2   0
##            P 129   0   0   0   1   0   2   0   0   1   0
##            Q   1 104   1   3   0   9   3   1   0   6   1
##            R   0   1 153  10   0   0   0   1   1   0   4
##            S   0   5   0 116   0   0   1   0   5   4  18
##            T   0   0   0   2 139   2   2   0   0  12   3
##            U   0   0   0   1   5 143   2   0   0   2   0
##            V   0   0   0   0   5   6 132   4   0  15   0
##            W   9   0   2   0   0   0  13 136   0   1   0
##            X   0   0   3  14   9   0   2   0 128   0   3
```

```
##           Y   6   1   0   1  11   2   3   0   9 122   0
##           Z   0   1   0   6   2   0   0   0   6   0 133
```

```
#Calculate misclassification rate
correct_letters <- sum(diag(conf_letters))
correct_letters
```

```
## [1] 3386
```

```
letters_mis <- (sum(conf_letters) - correct_letters)/sum(conf_letters)
letters_mis
```

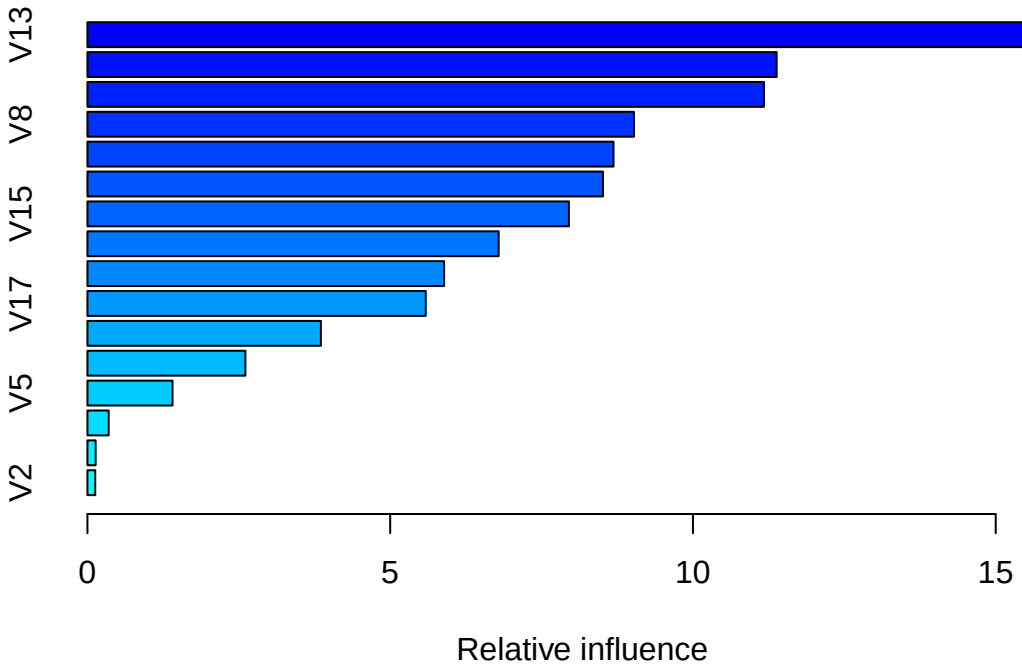
```
## [1] 0.3228
```

- The miscclassification rate of my model is 0.3228.
- H was the most difficult letter to distinguish
- E and X, H and O, Q ans G, Z and S, and T and Y seem to be the letter pairs that were the most difficult to distinguish from one another respectively.

Slow the learning

```
#Build second model
set.seed(40)
boost.slow = gbm(V1 ~., data = lettersdf[train,], distribution = "multinomial", n.trees = 300, interacti

summary(boost.slow)
```




```
##     var    rel.inf
## V13 V13 16.5140483
## V14 V14 11.3824856
## V12 V12 11.1730298
## V8   V8  9.0258553
## V11 V11  8.6878633
## V10 V10  8.5136065
## V15 V15  7.9510586
```

```
## V9   V9  6.7911016
## V16 V16  5.8901260
## V17 V17  5.5871830
## V7   V7  3.8554349
## V4   V4  2.6087180
## V5   V5  1.4051815
## V6   V6  0.3503772
## V3   V3  0.1353294
## V2   V2  0.1286010
```

```
#Predict letters
yhat.slow = predict(boost.slow, newdata = lettersdf[-train,], n.trees = 300, type = "response")
pred_slow<- LETTERS[apply(yhat.slow, 1, which.max)]
pred_slow
```

```
##    [1] "T" "K" "G" "B" "E" "H" "X" "X" "G" "W" "L" "Q" "H" "J" "R" "B" "W"
##   [18] "N" "Y" "D" "T" "T" "U" "N" "R" "Q" "E" "A" "L" "Z" "M" "A" "H" "B"
##   [35] "V" "S" "B" "N" "S" "I" "B" "P" "O" "K" "Z" "O" "L" "Q" "Z" "X" "P"
##   [52] "P" "P" "Z" "S" "C" "M" "L" "T" "T" "R" "G" "V" "Z" "M" "A" "O" "H"
##   [69] "I" "S" "T" "T" "X" "V" "A" "P" "O" "D" "F" "B" "K" "T" "Y" "X" "Q"
##   [86] "F" "M" "D" "Z" "S" "V" "X" "C" "J" "D" "D" "J" "I" "J" "M" "J" "Z"
##  [103] "N" "C" "Z" "W" "J" "M" "U" "B" "B" "N" "M" "B" "P" "D" "B" "S" "O"
##  [120] "B" "O" "N" "J" "S" "V" "B" "O" "Y" "X" "N" "E" "E" "V" "J" "A" "P"
##  [137] "H" "X" "N" "G" "T" "W" "F" "V" "B" "M" "M" "G" "B" "H" "K" "Y" "Q"
##  [154] "R" "B" "P" "S" "P" "H" "P" "D" "T" "J" "H" "A" "E" "I" "Y" "F" "P"
##  [171] "G" "I" "Y" "E" "K" "V" "X" "U" "D" "D" "Z" "X" "A" "Y" "A" "Z" "P"
##  [188] "S" "H" "T" "G" "L" "T" "Y" "S" "N" "G" "N" "B" "S" "G" "G" "S" "L"
##  [205] "G" "S" "R" "G" "I" "G" "K" "B" "M" "L" "T" "Y" "C" "Y" "S" "T" "S"
##  [222] "E" "L" "P" "N" "M" "S" "R" "D" "F" "T" "M" "Z" "S" "Q" "E" "K" "N"
##  [239] "D" "R" "T" "F" "W" "Y" "Y" "M" "A" "F" "A" "F" "S" "T" "A" "G" "O"
##  [256] "Z" "J" "E" "A" "C" "B" "D" "G" "U" "S" "J" "E" "H" "M" "B" "B" "Z"
##  [273] "T" "D" "U" "Z" "P" "D" "Y" "F" "B" "Y" "V" "E" "E" "X" "E" "Y" "P"
##  [290] "P" "X" "O" "G" "K" "X" "Z" "K" "I" "B" "C" "K" "O" "T" "F" "S" "J"
##  [307] "Y" "V" "B" "O" "E" "A" "T" "H" "C" "J" "J" "I" "U" "V" "M" "V" "I"
##  [324] "C" "R" "A" "E" "C" "F" "F" "Z" "H" "K" "A" "Q" "P" "G" "A" "T" "Q"
##  [341] "V" "G" "M" "B" "K" "B" "D" "A" "E" "V" "N" "X" "R" "N" "Y" "W" "D"
##  [358] "U" "S" "D" "Z" "L" "B" "U" "P" "R" "E" "I" "Q" "Q" "U" "K" "S" "T"
##  [375] "Z" "D" "C" "H" "X" "I" "P" "B" "Q" "G" "U" "J" "P" "I" "C" "I" "B"
##  [392] "M" "X" "P" "N" "O" "F" "O" "D" "V" "K" "W" "M" "K" "Z" "A" "C" "A"
##  [409] "V" "H" "O" "A" "T" "G" "W" "Z" "W" "G" "N" "K" "P" "L" "K" "K" "X"
##  [426] "S" "S" "H" "N" "H" "Q" "E" "R" "Y" "A" "U" "L" "O" "E" "K" "C" "T"
##  [443] "U" "N" "E" "J" "K" "S" "S" "H" "Y" "W" "F" "U" "N" "X" "V" "G" "C"
##  [460] "Y" "W" "B" "N" "N" "M" "L" "W" "C" "O" "A" "Q" "C" "U" "O" "S" "H"
##  [477] "L" "H" "R" "G" "A" "K" "O" "G" "U" "D" "X" "I" "O" "P" "A" "K" "G"
##  [494] "K" "A" "T" "Q" "Y" "R" "F" "R" "Y" "F" "G" "Q" "B" "C" "L" "H" "W"
##  [511] "B" "E" "T" "C" "E" "S" "Q" "Y" "D" "R" "I" "D" "V" "B" "V" "E" "F"
##  [528] "A" "U" "I" "O" "S" "T" "R" "F" "O" "M" "Y" "K" "H" "K" "O" "J" "S"
##  [545] "Q" "G" "Z" "C" "W" "S" "M" "P" "R" "C" "D" "Z" "K" "H" "U" "Q" "W"
##  [562] "W" "Q" "G" "U" "A" "R" "M" "U" "C" "U" "P" "J" "Z" "M" "I" "S" "N"
##  [579] "P" "Z" "A" "J" "J" "B" "G" "B" "K" "L" "O" "D" "I" "M" "N" "B" "O"
##  [596] "O" "S" "W" "F" "B" "U" "N" "T" "L" "E" "E" "O" "D" "K" "Q" "D" "H"
##  [613] "Q" "J" "A" "M" "Q" "B" "M" "T" "Q" "Z" "R" "B" "Z" "T" "Y" "R" "N"
##  [630] "X" "C" "Q" "F" "B" "P" "G" "R" "N" "F" "Q" "R" "G" "B" "R" "H" "Y"
##  [647] "A" "J" "Q" "W" "G" "T" "L" "K" "S" "C" "E" "A" "K" "M" "I" "H" "X"
##  [664] "F" "T" "M" "L" "V" "P" "S" "C" "X" "E" "L" "T" "B" "K" "V" "S" "H"
```

```
##  [681] "S" "V" "J" "L" "D" "O" "O" "E" "S" "T" "C" "A" "O" "L" "N" "T" "Z"
##  [698] "N" "P" "I" "E" "F" "I" "F" "Y" "Q" "T" "Q" "L" "S" "X" "H" "G" "P"
##  [715] "A" "B" "V" "A" "R" "G" "D" "U" "U" "M" "R" "C" "B" "G" "M" "Z" "P"
##  [732] "K" "A" "M" "B" "Q" "Q" "M" "F" "X" "N" "R" "R" "M" "X" "Q" "R" "C"
##  [749] "B" "U" "U" "Z" "W" "T" "Z" "J" "T" "Q" "O" "H" "D" "F" "O" "Q" "J"
##  [766] "Y" "I" "V" "C" "Q" "Y" "K" "F" "I" "Q" "N" "B" "V" "Y" "Z" "F" "R"
##  [783] "I" "P" "H" "F" "Y" "E" "C" "O" "F" "E" "Y" "D" "W" "M" "L" "Y" "H"
##  [800] "R" "D" "E" "O" "D" "F" "A" "C" "V" "T" "S" "Y" "W" "T" "K" "B" "L"
##  [817] "O" "G" "C" "Z" "I" "O" "U" "J" "G" "S" "T" "V" "O" "Q" "H" "T" "R"
##  [834] "R" "G" "J" "E" "D" "K" "O" "S" "U" "H" "Z" "I" "D" "H" "W" "B" "S"
##  [851] "V" "O" "U" "E" "U" "J" "G" "C" "O" "D" "C" "K" "A" "F" "E" "M" "W"
##  [868] "Q" "A" "F" "H" "N" "E" "M" "H" "T" "I" "X" "L" "W" "U" "Q" "F" "C"
##  [885] "S" "X" "S" "Z" "J" "W" "I" "I" "Y" "V" "O" "R" "K" "J" "F" "S" "G"
##  [902] "T" "P" "U" "W" "C" "S" "L" "S" "A" "M" "S" "M" "X" "H" "Q" "S" "F"
##  [919] "X" "X" "L" "O" "T" "N" "D" "O" "R" "O" "V" "N" "M" "K" "O" "B" "G"
##  [936] "K" "Y" "S" "W" "Y" "G" "T" "E" "G" "P" "Q" "N" "M" "T" "B" "O" "I"
##  [953] "K" "Z" "A" "M" "I" "U" "H" "X" "B" "H" "Z" "Q" "X" "D" "U" "R" "R"
##  [970] "Z" "A" "V" "G" "B" "X" "J" "J" "Z" "W" "B" "C" "M" "R" "Y" "R" "S"
##  [987] "N" "E" "J" "G" "S" "F" "N" "Q" "K" "Q" "Z" "R" "W" "H" "B" "T" "J"
## [1004] "C" "J" "U" "G" "M" "Z" "N" "L" "R" "K" "I" "K" "P" "U" "I" "N" "B"
## [1021] "X" "P" "U" "X" "T" "K" "J" "F" "F" "L" "P" "P" "C" "Y" "S" "Q" "D"
## [1038] "O" "A" "F" "F" "X" "L" "A" "P" "E" "T" "M" "Y" "G" "U" "I" "H" "G"
## [1055] "B" "A" "B" "G" "F" "P" "R" "K" "Y" "R" "B" "C" "J" "P" "A" "U" "C"
## [1072] "F" "A" "B" "Y" "A" "F" "H" "N" "L" "Z" "E" "N" "O" "S" "G" "T" "M"
## [1089] "S" "C" "G" "B" "Y" "V" "Y" "T" "I" "L" "P" "U" "E" "R" "M" "Q" "X"
## [1106] "U" "N" "Z" "I" "K" "F" "U" "R" "X" "F" "O" "R" "B" "N" "V" "Q" "K"
## [1123] "B" "R" "L" "S" "Y" "M" "B" "E" "H" "Y" "B" "X" "S" "B" "A" "B" "N"
## [1140] "E" "C" "W" "V" "H" "Z" "D" "G" "L" "G" "R" "L" "T" "C" "L" "X" "A"
## [1157] "Y" "Z" "M" "U" "E" "U" "W" "M" "R" "V" "B" "T" "O" "P" "F" "M" "R"
## [1174] "P" "X" "R" "K" "D" "R" "L" "B" "R" "T" "J" "U" "E" "Z" "Y" "I" "Q"
## [1191] "A" "T" "D" "Q" "A" "J" "F" "L" "C" "U" "I" "P" "F" "Y" "V" "G" "J"
## [1208] "A" "U" "O" "D" "M" "Q" "O" "Y" "D" "F" "M" "L" "J" "R" "V" "M" "F"
## [1225] "E" "V" "Y" "I" "H" "R" "I" "A" "S" "H" "B" "J" "O" "O" "D" "G" "J"
## [1242] "T" "N" "Y" "H" "F" "C" "H" "K" "L" "Y" "S" "E" "I" "F" "O" "O" "Q"
## [1259] "U" "M" "S" "N" "E" "V" "N" "T" "Q" "J" "A" "D" "G" "U" "S" "U" "G"
## [1276] "Q" "T" "E" "M" "D" "I" "E" "D" "Y" "O" "T" "H" "B" "T" "J" "L" "S"
## [1293] "P" "M" "I" "N" "C" "X" "Q" "B" "C" "S" "L" "W" "K" "S" "A" "T" "B"
## [1310] "V" "R" "Z" "Y" "T" "X" "D" "K" "X" "S" "U" "M" "N" "T" "D" "T" "G"
## [1327] "W" "H" "W" "N" "B" "G" "Q" "M" "Z" "U" "T" "K" "O" "U" "R" "M" "G"
## [1344] "G" "X" "X" "T" "V" "X" "L" "H" "P" "I" "H" "E" "W" "A" "S" "D" "L"
## [1361] "W" "A" "P" "N" "K" "M" "R" "N" "M" "Z" "B" "E" "Z" "W" "H" "K" "J"
## [1378] "B" "U" "X" "F" "C" "S" "D" "X" "U" "W" "T" "A" "C" "H" "W" "N" "K"
## [1395] "B" "S" "V" "B" "P" "U" "O" "U" "F" "N" "B" "R" "O" "F" "R" "X" "Z"
## [1412] "L" "O" "V" "A" "K" "S" "T" "L" "P" "C" "X" "R" "Y" "Q" "C" "S" "I"
## [1429] "Y" "A" "F" "E" "J" "W" "C" "B" "U" "M" "F" "Y" "Q" "B" "E" "A" "U"
## [1446] "M" "O" "B" "D" "S" "C" "N" "D" "X" "B" "O" "S" "S" "A" "Z" "M" "J"
## [1463] "I" "O" "E" "M" "N" "B" "X" "R" "N" "P" "M" "O" "T" "D" "B" "G" "D"
## [1480] "S" "E" "Z" "E" "I" "S" "T" "N" "K" "B" "V" "I" "K" "G" "W" "G" "F"
## [1497] "D" "A" "I" "Q" "U" "N" "K" "R" "L" "X" "V" "P" "Y" "K" "D" "S" "G"
## [1514] "C" "V" "V" "O" "E" "D" "H" "Q" "E" "E" "R" "J" "W" "V" "X" "A" "H"
## [1531] "I" "F" "S" "E" "K" "Z" "K" "T" "L" "O" "L" "M" "O" "Q" "X" "R" "V"
## [1548] "I" "K" "S" "Y" "G" "M" "Z" "C" "L" "M" "T" "C" "X" "W" "B" "W" "U"
## [1565] "N" "U" "X" "W" "M" "D" "O" "K" "B" "L" "L" "S" "O" "I" "D" "U" "X"
## [1582] "J" "T" "A" "F" "D" "Z" "W" "V" "X" "Y" "K" "E" "L" "C" "G" "U" "O"
```

```
## [1599] "X" "K" "O" "L" "E" "U" "C" "O" "I" "Q" "I" "B" "O" "V" "W" "P" "E"
## [1616] "E" "F" "V" "G" "U" "J" "L" "D" "A" "C" "K" "Y" "F" "E" "O" "E" "P"
## [1633] "N" "Y" "S" "Z" "P" "L" "W" "M" "F" "L" "S" "M" "D" "C" "V" "R" "K"
## [1650] "R" "G" "N" "T" "L" "F" "J" "U" "C" "B" "B" "D" "J" "O" "R" "C" "D"
## [1667] "E" "O" "S" "J" "X" "A" "V" "D" "Y" "N" "A" "H" "Y" "T" "K" "I" "Y"
## [1684] "X" "U" "R" "W" "Q" "M" "O" "X" "F" "H" "C" "S" "I" "N" "U" "J" "M"
## [1701] "D" "G" "L" "X" "D" "N" "O" "H" "C" "S" "R" "R" "S" "J" "M" "H" "Q"
## [1718] "G" "J" "G" "H" "J" "P" "V" "C" "D" "X" "K" "R" "F" "K" "T" "Y" "T"
## [1735] "T" "X" "E" "O" "Q" "D" "A" "K" "T" "P" "R" "X" "F" "L" "O" "L" "C"
## [1752] "L" "R" "R" "Z" "B" "O" "H" "Y" "O" "R" "O" "T" "Y" "N" "K" "S" "L"
## [1769] "N" "X" "V" "Q" "A" "O" "K" "G" "M" "M" "B" "R" "O" "N" "R" "V" "T"
## [1786] "S" "Y" "I" "W" "C" "D" "N" "W" "A" "Z" "M" "T" "G" "O" "K" "F" "Q"
## [1803] "H" "U" "R" "I" "X" "R" "T" "I" "C" "M" "D" "Z" "E" "L" "I" "H" "O"
## [1820] "K" "A" "P" "U" "H" "E" "F" "V" "I" "T" "O" "H" "Y" "S" "Q" "T" "D"
## [1837] "F" "S" "L" "E" "P" "T" "W" "N" "R" "Q" "W" "B" "C" "J" "O" "V" "R"
## [1854] "P" "J" "D" "J" "V" "H" "J" "S" "B" "G" "Z" "J" "R" "Q" "U" "S" "F"
## [1871] "P" "Q" "F" "F" "T" "K" "V" "M" "Q" "M" "A" "Y" "A" "E" "K" "C" "M"
## [1888] "W" "G" "O" "A" "K" "E" "X" "B" "Y" "R" "C" "G" "P" "U" "T" "H" "O"
## [1905] "E" "D" "P" "O" "R" "Y" "G" "R" "P" "F" "E" "N" "O" "N" "N" "H" "C"
## [1922] "Z" "Y" "K" "P" "E" "K" "S" "B" "L" "S" "P" "D" "R" "U" "S" "Z" "D"
## [1939] "Z" "X" "M" "U" "N" "F" "K" "L" "V" "Z" "K" "S" "L" "C" "U" "J" "G"
## [1956] "X" "T" "K" "P" "S" "O" "W" "O" "E" "S" "O" "K" "K" "T" "F" "N" "S"
## [1973] "H" "M" "L" "P" "N" "U" "I" "W" "F" "S" "X" "H" "X" "G" "U" "Z" "F"
## [1990] "N" "N" "D" "B" "S" "A" "B" "V" "D" "W" "O" "W" "Q" "B" "K" "W" "U"
## [2007] "K" "A" "R" "X" "L" "E" "C" "J" "C" "U" "T" "P" "B" "N" "D" "I" "B"
## [2024] "D" "L" "A" "P" "P" "W" "Q" "V" "R" "C" "P" "T" "R" "A" "A" "K" "L"
## [2041] "A" "U" "T" "W" "G" "P" "E" "B" "V" "L" "P" "D" "Z" "B" "H" "Q" "K"
## [2058] "N" "J" "P" "F" "B" "R" "K" "P" "N" "B" "X" "N" "K" "O" "U" "P" "J"
## [2075] "B" "Z" "G" "V" "S" "U" "L" "U" "W" "P" "N" "Z" "Z" "C" "Y" "G" "E"
## [2092] "B" "R" "M" "M" "Y" "C" "H" "P" "B" "Q" "D" "D" "V" "U" "U" "X" "M"
## [2109] "S" "E" "D" "L" "I" "P" "M" "P" "R" "D" "X" "Z" "M" "V" "W" "F" "U"
## [2126] "O" "Q" "Z" "F" "I" "H" "C" "H" "P" "J" "Q" "E" "H" "A" "E" "G" "Q"
## [2143] "H" "V" "G" "T" "S" "U" "Y" "D" "E" "Z" "N" "J" "K" "G" "L" "R" "A"
## [2160] "N" "O" "Z" "K" "C" "F" "K" "D" "W" "G" "J" "H" "Z" "Z" "B" "S" "W"
## [2177] "I" "O" "Q" "F" "V" "U" "P" "L" "Q" "M" "Y" "C" "D" "Y" "O" "H" "H"
## [2194] "U" "D" "B" "X" "C" "P" "F" "B" "L" "P" "M" "L" "B" "F" "Z" "X" "U"
## [2211] "C" "M" "D" "Y" "B" "J" "V" "D" "O" "M" "T" "M" "I" "X" "C" "I" "K"
## [2228] "O" "R" "P" "M" "R" "H" "A" "P" "O" "S" "V" "S" "F" "N" "A" "Y" "V"
## [2245] "A" "I" "T" "N" "Q" "U" "O" "D" "J" "A" "I" "M" "Z" "R" "T" "R" "B"
## [2262] "A" "X" "F" "V" "O" "W" "I" "R" "X" "X" "Y" "U" "F" "D" "N" "S" "I"
## [2279] "T" "D" "R" "F" "B" "U" "B" "K" "Z" "S" "I" "U" "N" "M" "B" "E" "P"
## [2296] "I" "M" "Z" "Z" "X" "C" "P" "W" "O" "A" "G" "U" "N" "W" "V" "N" "K"
## [2313] "Q" "Z" "M" "T" "S" "L" "Z" "F" "I" "M" "P" "C" "Q" "C" "A" "V" "D"
## [2330] "D" "R" "D" "F" "Q" "T" "Z" "M" "C" "N" "O" "N" "G" "G" "C" "Y" "R"
## [2347] "C" "G" "A" "I" "S" "B" "Z" "F" "O" "I" "H" "S" "V" "L" "W" "M" "F"
## [2364] "Y" "P" "L" "N" "Y" "O" "S" "I" "T" "P" "R" "W" "N" "X" "M" "A" "M"
## [2381] "C" "I" "T" "G" "W" "B" "Q" "X" "Y" "Q" "V" "N" "U" "L" "O" "E" "F"
## [2398] "I" "G" "T" "P" "Q" "M" "O" "H" "C" "O" "E" "Q" "I" "C" "O" "W" "E"
## [2415] "Z" "B" "H" "Y" "M" "V" "W" "X" "E" "R" "V" "N" "K" "M" "H" "V" "W"
## [2432] "S" "X" "A" "M" "Q" "B" "W" "L" "O" "L" "U" "W" "P" "O" "B" "Z" "C"
## [2449] "R" "J" "U" "Q" "W" "F" "L" "M" "B" "I" "C" "E" "J" "Q" "R" "T" "O"
## [2466] "V" "A" "V" "C" "K" "S" "U" "J" "D" "L" "E" "G" "I" "H" "I" "I" "O"
## [2483] "D" "N" "N" "I" "S" "O" "L" "C" "I" "J" "D" "R" "F" "X" "T" "B" "D"
## [2500] "Q" "B" "M" "R" "V" "M" "B" "M" "C" "Z" "S" "S" "Q" "Q" "F" "U" "A"
```

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## [2517] "U" "V" "Z" "O" "W" "K" "T" "D" "X" "A" "I" "X" "T" "R" "B" "W" "C"
## [2534] "V" "J" "D" "L" "L" "R" "U" "F" "M" "C" "M" "A" "N" "V" "M" "G" "O"
## [2551] "J" "T" "M" "Q" "U" "H" "M" "O" "H" "C" "K" "X" "P" "Z" "J" "M" "N"
## [2568] "Z" "O" "O" "X" "D" "J" "Y" "P" "G" "W" "I" "G" "Q" "Y" "L" "Q" "V"
## [2585] "R" "Q" "J" "D" "K" "J" "B" "W" "R" "Q" "V" "L" "N" "E" "B" "Y" "R"
## [2602] "Q" "O" "M" "U" "G" "L" "V" "W" "L" "R" "M" "U" "O" "C" "V" "X" "T"
## [2619] "W" "P" "B" "T" "A" "R" "E" "G" "N" "M" "L" "O" "W" "S" "X" "M" "E"
## [2636] "T" "R" "U" "Y" "S" "A" "T" "A" "O" "S" "K" "S" "R" "N" "C" "G" "E"
## [2653] "A" "H" "M" "S" "T" "B" "F" "E" "Q" "O" "N" "W" "V" "K" "B" "X" "O"
## [2670] "N" "O" "O" "P" "O" "B" "C" "R" "V" "F" "N" "L" "D" "Y" "L" "K" "L"
## [2687] "R" "M" "R" "B" "A" "X" "A" "H" "P" "W" "L" "L" "P" "X" "S" "V" "W"
## [2704] "F" "X" "V" "O" "Y" "X" "K" "M" "D" "S" "C" "G" "E" "D" "R" "I" "J"
## [2721] "G" "N" "P" "N" "H" "G" "S" "W" "P" "M" "X" "Y" "D" "D" "E" "M" "W"
## [2738] "N" "E" "D" "L" "U" "X" "O" "R" "A" "Q" "M" "N" "D" "C" "K" "A" "H"
## [2755] "C" "F" "Y" "W" "Z" "P" "O" "B" "D" "X" "B" "K" "K" "O" "B" "P" "B"
## [2772] "L" "D" "A" "N" "G" "A" "O" "V" "M" "M" "X" "M" "F" "X" "O" "H" "X"
## [2789] "T" "I" "J" "P" "W" "M" "X" "Q" "J" "D" "X" "O" "O" "G" "I" "L" "A"
## [2806] "T" "P" "M" "K" "X" "E" "X" "J" "W" "K" "T" "R" "H" "N" "H" "R" "O"
## [2823] "X" "P" "T" "G" "O" "O" "S" "M" "U" "T" "E" "R" "V" "J" "R" "S" "X"
## [2840] "P" "J" "E" "C" "D" "W" "M" "E" "M" "E" "C" "N" "B" "W" "S" "V" "K"
## [2857] "M" "G" "O" "K" "T" "I" "H" "B" "N" "Q" "J" "V" "M" "M" "Y" "T" "I"
## [2874] "O" "M" "F" "F" "A" "W" "E" "V" "D" "R" "K" "R" "C" "Z" "K" "K" "S"
## [2891] "B" "H" "N" "Z" "C" "P" "E" "Z" "X" "J" "U" "R" "V" "Y" "B" "D" "C"
## [2908] "S" "A" "C" "A" "W" "L" "R" "R" "O" "S" "S" "A" "U" "H" "Y" "K" "G"
## [2925] "P" "U" "J" "B" "K" "X" "U" "N" "X" "U" "X" "B" "B" "N" "A" "E" "I"
## [2942] "M" "N" "A" "F" "Y" "Y" "R" "U" "N" "X" "W" "I" "Y" "K" "R" "V" "X"
## [2959] "O" "B" "T" "U" "M" "Q" "W" "M" "L" "R" "M" "R" "G" "X" "V" "W" "Q"
## [2976] "R" "K" "B" "Z" "T" "L" "L" "W" "W" "B" "O" "V" "I" "B" "H" "V" "J"
## [2993] "S" "W" "T" "B" "G" "P" "E" "W" "D" "C" "P" "Z" "U" "C" "A" "B" "V"
## [3010] "S" "O" "X" "W" "W" "Q" "G" "J" "L" "B" "A" "R" "I" "Q" "V" "A" "L"
## [3027] "J" "G" "S" "I" "F" "R" "O" "Y" "P" "M" "D" "S" "J" "J" "B" "Y" "H"
## [3044] "N" "L" "C" "N" "S" "D" "F" "D" "Y" "G" "Q" "G" "K" "D" "P" "W" "Q"
## [3061] "P" "L" "O" "U" "O" "Y" "D" "D" "O" "X" "D" "I" "V" "Q" "E" "D" "P"
## [3078] "C" "M" "G" "S" "D" "S" "C" "R" "N" "M" "D" "M" "K" "G" "L" "V" "D"
## [3095] "Q" "S" "V" "Z" "R" "U" "A" "U" "F" "W" "K" "B" "X" "X" "V" "I" "Q"
## [3112] "T" "A" "L" "G" "T" "M" "M" "T" "J" "X" "X" "N" "Q" "Q" "E" "G" "C"
## [3129] "Y" "Y" "H" "N" "E" "J" "U" "Z" "S" "S" "D" "X" "Q" "O" "D" "L" "O"
## [3146] "C" "I" "B" "W" "W" "S" "M" "A" "H" "O" "Y" "I" "G" "U" "M" "R" "S"
## [3163] "J" "K" "G" "E" "H" "O" "P" "N" "S" "B" "P" "Z" "P" "T" "Q" "W" "P"
## [3180] "U" "C" "R" "O" "P" "I" "N" "P" "L" "R" "X" "P" "M" "K" "Q" "Z" "K"
## [3197] "O" "U" "I" "O" "E" "E" "K" "C" "A" "W" "R" "H" "O" "S" "W" "A" "Y"
## [3214] "N" "D" "L" "L" "R" "F" "O" "T" "M" "E" "C" "Q" "P" "O" "U" "K" "G"
## [3231] "C" "X" "S" "V" "S" "E" "U" "A" "A" "O" "O" "K" "U" "S" "V" "F" "F"
## [3248] "J" "K" "B" "J" "K" "T" "A" "I" "D" "W" "H" "T" "X" "S" "C" "J" "N"
## [3265] "B" "Y" "P" "Z" "S" "V" "J" "W" "M" "B" "F" "N" "F" "O" "R" "J" "N"
## [3282] "A" "L" "I" "B" "P" "A" "Y" "T" "U" "Z" "Y" "D" "K" "H" "L" "W" "J"
## [3299] "Z" "G" "B" "O" "M" "G" "M" "M" "P" "D" "G" "H" "W" "E" "J" "Y" "W"
## [3316] "Z" "I" "M" "R" "Z" "A" "I" "Y" "Y" "L" "V" "O" "E" "R" "O" "P" "Q"
## [3333] "T" "B" "N" "J" "D" "E" "X" "Z" "J" "U" "U" "S" "V" "P" "I" "C" "T"
## [3350] "E" "P" "L" "U" "Q" "H" "D" "A" "V" "A" "R" "M" "U" "Q" "E" "I" "V"
## [3367] "W" "T" "S" "E" "K" "Y" "F" "X" "I" "T" "M" "X" "I" "A" "Y" "B" "V"
## [3384] "B" "O" "J" "K" "C" "D" "P" "B" "F" "K" "P" "H" "V" "P" "E" "B" "Z"
## [3401] "L" "E" "V" "W" "Y" "U" "X" "R" "P" "E" "X" "T" "C" "D" "J" "M" "N"
## [3418] "S" "C" "I" "Y" "S" "L" "O" "I" "K" "E" "F" "G" "P" "N" "N" "J" "W"
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## [3435] "D" "L" "D" "L" "F" "D" "O" "P" "Q" "B" "G" "E" "O" "B" "R" "Q" "R"
## [3452] "P" "D" "L" "O" "I" "P" "O" "A" "V" "M" "N" "Q" "J" "K" "F" "S" "Z"
## [3469] "X" "S" "P" "O" "E" "X" "D" "Z" "K" "F" "U" "K" "F" "K" "P" "Y" "O"
## [3486] "U" "G" "I" "O" "H" "S" "I" "C" "C" "M" "Y" "O" "E" "I" "R" "I" "Z"
## [3503] "V" "H" "O" "D" "B" "D" "K" "D" "H" "U" "H" "F" "W" "B" "X" "J" "I"
## [3520] "Q" "V" "S" "Q" "C" "Y" "D" "M" "S" "B" "C" "E" "H" "T" "F" "E" "F"
## [3537] "G" "V" "H" "L" "X" "S" "P" "Y" "L" "O" "Y" "D" "U" "F" "X" "K" "S"
## [3554] "F" "L" "L" "L" "L" "F" "X" "X" "K" "Q" "Z" "U" "G" "Z" "M" "T" "R"
## [3571] "L" "C" "Q" "R" "R" "S" "Q" "V" "A" "B" "S" "Y" "C" "P" "W" "P" "Q"
## [3588] "U" "O" "O" "T" "X" "N" "H" "V" "D" "O" "Y" "M" "O" "Q" "T" "Z" "Q"
## [3605] "V" "Y" "R" "A" "G" "P" "J" "Q" "W" "H" "E" "C" "Q" "D" "I" "V" "Y"
## [3622] "K" "Q" "O" "W" "L" "W" "R" "M" "D" "H" "C" "A" "N" "U" "U" "O" "H"
## [3639] "M" "R" "F" "K" "G" "R" "F" "U" "A" "W" "X" "Z" "O" "M" "M" "U" "V"
## [3656] "C" "H" "B" "C" "W" "A" "S" "T" "L" "L" "P" "Z" "L" "Z" "W" "J" "R"
## [3673] "T" "M" "A" "F" "I" "A" "F" "E" "P" "R" "A" "R" "G" "N" "D" "S" "R"
## [3690] "O" "J" "N" "B" "A" "Q" "Y" "H" "U" "N" "F" "F" "N" "V" "V" "F" "V"
## [3707] "I" "W" "M" "Z" "P" "E" "V" "P" "L" "J" "P" "D" "O" "F" "A" "I" "N"
## [3724] "M" "A" "D" "I" "B" "T" "R" "L" "W" "O" "E" "X" "H" "R" "H" "F" "R"
## [3741] "V" "Y" "I" "A" "O" "P" "N" "M" "L" "T" "N" "I" "M" "N" "W" "B" "G"
## [3758] "S" "U" "D" "U" "G" "O" "E" "T" "B" "A" "H" "M" "W" "F" "G" "Z" "A"
## [3775] "A" "P" "D" "H" "B" "B" "Q" "H" "Z" "M" "F" "H" "Z" "M" "M" "F" "E"
## [3792] "V" "L" "R" "G" "W" "I" "X" "J" "A" "W" "G" "M" "B" "T" "L" "Y" "Q"
## [3809] "E" "S" "U" "D" "K" "D" "H" "G" "C" "I" "S" "N" "G" "O" "A" "W" "E"
## [3826] "I" "S" "W" "M" "L" "H" "F" "I" "A" "U" "B" "U" "A" "G" "P" "I" "L"
## [3843] "I" "Z" "Z" "N" "Z" "C" "O" "A" "Y" "L" "W" "N" "C" "G" "Q" "J" "B"
## [3860] "J" "M" "G" "L" "A" "K" "H" "L" "O" "B" "U" "M" "S" "T" "L" "F" "A"
## [3877] "C" "N" "K" "Y" "H" "B" "L" "Q" "Y" "I" "W" "F" "D" "N" "Z" "M" "Z"
## [3894] "W" "I" "W" "N" "K" "J" "J" "H" "O" "X" "U" "Q" "B" "Y" "O" "P" "S"
## [3911] "R" "P" "F" "U" "L" "L" "K" "Z" "W" "T" "G" "G" "V" "O" "Z" "R" "J"
## [3928] "K" "R" "U" "B" "L" "C" "N" "M" "X" "J" "Y" "S" "A" "X" "R" "I" "K"
## [3945] "Y" "U" "R" "J" "G" "M" "F" "S" "G" "L" "U" "O" "B" "A" "U" "I" "E"
## [3962] "K" "U" "J" "X" "P" "V" "F" "U" "C" "G" "Z" "N" "S" "A" "B" "H" "K"
## [3979] "S" "I" "A" "E" "G" "M" "T" "N" "X" "O" "E" "D" "T" "Y" "W" "N" "R"
## [3996] "Z" "P" "B" "E" "O" "P" "E" "D" "J" "B" "T" "W" "I" "Z" "F" "M" "N"
## [4013] "Y" "G" "L" "Q" "R" "R" "D" "C" "B" "R" "R" "H" "C" "A" "N" "H" "E"
## [4030] "K" "Q" "O" "W" "Q" "H" "T" "I" "D" "O" "G" "B" "Y" "S" "A" "I" "X"
## [4047] "K" "I" "W" "I" "J" "P" "G" "G" "L" "V" "U" "K" "U" "W" "F" "P" "P"
## [4064] "U" "I" "B" "U" "X" "A" "Y" "S" "K" "O" "K" "G" "E" "L" "J" "O" "J"
## [4081] "L" "G" "L" "G" "Q" "V" "X" "I" "I" "N" "H" "S" "C" "P" "K" "K" "H"
## [4098] "N" "Y" "U" "D" "O" "C" "B" "D" "O" "H" "S" "K" "O" "N" "Z" "W" "Y"
## [4115] "I" "V" "N" "S" "T" "M" "W" "F" "S" "B" "B" "O" "N" "Z" "H" "A" "U"
## [4132] "X" "T" "L" "B" "W" "V" "S" "R" "L" "F" "Z" "J" "C" "T" "E" "X" "D"
## [4149] "F" "E" "G" "K" "A" "R" "R" "B" "N" "I" "B" "W" "I" "E" "M" "K" "L"
## [4166] "S" "Z" "N" "H" "C" "L" "D" "I" "D" "J" "H" "K" "A" "Y" "L" "I" "N"
## [4183] "L" "W" "E" "R" "O" "X" "T" "H" "V" "M" "S" "Z" "U" "T" "D" "D" "C"
## [4200] "K" "N" "A" "K" "M" "W" "D" "S" "D" "Y" "I" "B" "P" "F" "E" "O" "S"
## [4217] "W" "D" "L" "D" "P" "E" "U" "R" "B" "R" "H" "M" "O" "Y" "M" "S" "J"
## [4234] "A" "B" "C" "J" "J" "J" "V" "Z" "X" "Y" "D" "K" "Y" "X" "F" "R" "B"
## [4251] "B" "U" "T" "K" "B" "B" "E" "A" "A" "J" "R" "I" "R" "T" "W" "G" "B"
## [4268] "G" "O" "R" "Y" "W" "C" "V" "R" "O" "X" "G" "K" "N" "H" "V" "X" "J"
## [4285] "L" "N" "Q" "A" "R" "V" "Q" "Y" "P" "R" "S" "L" "J" "D" "E" "V" "E"
## [4302] "Q" "B" "Q" "Q" "U" "A" "Z" "X" "T" "J" "T" "Y" "J" "M" "D" "H" "W"
## [4319] "W" "A" "X" "A" "N" "T" "B" "B" "U" "D" "V" "N" "J" "F" "L" "I" "D"
## [4336] "I" "I" "R" "I" "X" "F" "O" "Q" "F" "C" "H" "Q" "N" "Z" "Q" "Y" "U"
```

```
## [4353] "G" "R" "R" "F" "P" "Q" "X" "B" "H" "T" "V" "P" "Y" "K" "E" "C" "H"
## [4370] "V" "W" "S" "Q" "Z" "P" "D" "A" "R" "F" "X" "M" "L" "Z" "O" "N" "M"
## [4387] "E" "S" "X" "M" "M" "O" "B" "X" "H" "S" "X" "Z" "A" "C" "S" "K" "L"
## [4404] "L" "P" "P" "Z" "S" "V" "X" "R" "S" "K" "W" "V" "X" "F" "Q" "F" "T"
## [4421] "K" "X" "O" "I" "L" "B" "K" "R" "F" "M" "L" "M" "F" "R" "U" "U" "Q"
## [4438] "K" "I" "Q" "T" "B" "V" "V" "S" "N" "B" "X" "S" "A" "S" "Q" "Q" "J"
## [4455] "G" "T" "S" "L" "C" "B" "G" "G" "Z" "T" "W" "I" "T" "P" "S" "H" "N"
## [4472] "H" "P" "G" "B" "I" "A" "A" "B" "I" "Q" "S" "G" "W" "D" "W" "L" "Q"
## [4489] "K" "I" "R" "O" "A" "G" "J" "U" "I" "T" "F" "W" "D" "A" "H" "F" "U"
## [4506] "W" "Q" "D" "I" "Z" "W" "Y" "L" "X" "G" "X" "J" "H" "K" "C" "M" "G"
## [4523] "D" "U" "B" "E" "Z" "R" "A" "I" "K" "P" "G" "B" "R" "K" "D" "R" "Q"
## [4540] "K" "I" "R" "F" "Q" "W" "U" "X" "E" "M" "G" "B" "F" "R" "D" "D" "J"
## [4557] "Z" "J" "K" "Z" "O" "Y" "T" "D" "P" "H" "Y" "X" "W" "Y" "P" "U" "S"
## [4574] "N" "T" "F" "G" "V" "C" "J" "Z" "G" "Z" "S" "X" "N" "H" "B" "Z" "M"
## [4591] "E" "A" "J" "A" "K" "Z" "I" "S" "T" "N" "L" "M" "O" "L" "Y" "J" "K"
## [4608] "T" "T" "V" "R" "Z" "R" "C" "X" "H" "C" "A" "M" "E" "T" "E" "L" "A"
## [4625] "M" "A" "Z" "V" "N" "B" "L" "A" "I" "O" "J" "T" "Z" "M" "G" "E" "W"
## [4642] "U" "H" "M" "B" "W" "X" "V" "L" "A" "F" "B" "K" "Z" "N" "B" "B" "X"
## [4659] "V" "N" "Z" "C" "X" "I" "W" "O" "A" "K" "D" "O" "G" "N" "M" "Z" "W"
## [4676] "S" "M" "F" "X" "Y" "Q" "W" "Q" "F" "G" "F" "I" "X" "O" "X" "X" "A"
## [4693] "I" "B" "O" "R" "I" "N" "S" "Y" "T" "D" "T" "X" "C" "I" "F" "U" "V"
## [4710] "I" "X" "Q" "F" "Y" "P" "U" "A" "H" "C" "S" "H" "Z" "Q" "D" "S" "D"
## [4727] "I" "C" "N" "C" "R" "R" "L" "O" "L" "U" "G" "N" "W" "B" "X" "Z" "W"
## [4744] "J" "Z" "K" "U" "E" "C" "J" "O" "S" "V" "T" "M" "O" "X" "B" "K" "G"
## [4761] "B" "Y" "H" "C" "M" "E" "M" "J" "L" "A" "K" "A" "E" "Q" "K" "N" "T"
## [4778] "M" "I" "K" "G" "R" "Q" "N" "D" "J" "W" "W" "V" "C" "O" "A" "M" "P"
## [4795] "S" "M" "Q" "A" "D" "A" "T" "J" "D" "R" "P" "N" "F" "D" "W" "R" "D"
## [4812] "X" "I" "Q" "E" "D" "H" "C" "O" "X" "K" "E" "R" "G" "B" "W" "D" "Y"
## [4829] "D" "F" "T" "H" "U" "X" "A" "Y" "S" "H" "R" "P" "M" "W" "X" "M" "W"
## [4846] "N" "D" "K" "Z" "L" "D" "U" "B" "G" "I" "E" "L" "G" "U" "R" "H" "E"
## [4863] "U" "V" "T" "J" "I" "F" "O" "N" "H" "W" "P" "U" "M" "J" "B" "F" "T"
## [4880] "O" "L" "P" "Z" "J" "D" "G" "F" "Y" "V" "K" "D" "N" "P" "Y" "R" "B"
## [4897] "S" "W" "A" "B" "F" "J" "F" "C" "R" "V" "Z" "Z" "D" "T" "B" "R" "M"
## [4914] "T" "V" "A" "C" "P" "D" "T" "E" "W" "E" "Q" "G" "X" "M" "C" "E" "X"
## [4931] "D" "M" "F" "L" "J" "Q" "D" "C" "N" "R" "Q" "X" "J" "O" "S" "T" "M"
## [4948] "T" "S" "J" "K" "E" "R" "G" "I" "K" "F" "J" "I" "G" "W" "P" "I" "P"
## [4965] "D" "T" "V" "M" "G" "J" "R" "M" "X" "Y" "E" "X" "M" "Y" "Q" "J" "G"
## [4982] "Y" "Y" "N" "G" "X" "K" "O" "J" "Q" "F" "K" "W" "S" "M" "O" "X" "X"
## [4999] "T" "A"
```

```
#Build congudion mmatrix
conf_slow<- table(pred_slow, lettersdf[-train,]$V1)
conf_slow
```

```
##
## pred_slow   A   B   C   D   E   F   G   H   I   J   K   L   M   N   O   P
##         A 181   0   0   0   0   0   1   1   1   0   2   1   3   0   0   0
##         B   0 139   0  16   0   8   4   9   8   7   4   1   1   2   0   6
##         C   3   0 136   0   9   0  15   0   2   0   0   4   0   1   1   0
##         D   0   8   0 145   0   2   4  10   4   4   5   0   1   4   8   2
##         E   0   1   5   0 133   4   1   0   0   0   3   2   0   0   0   2
##         F   0   1   0   5   0 135   0   3   1   4   0   0   0   0   0  15
##         G   1   1  10   0   8   7 131   1   0   0   2   5   2   0   3   3
##         H   0   4   0   8   0   0   2 125   1   0   9   0   2   2   1   0
##         I   1   0   0   0   0   8   0   0 164   3   0   0   0   0   0   3
```

```
##         J   0   0   0   7   0   1   0   0   3 150   0   0   0   1   0   1
##         K   1   1  15   5   9   0   1  11   0   1 132   2   2   1   0   0
##         L   1   0   1   0   6   0   1   0   0   0   0 163   0   0   3   0
##         M   2   5   0   0   0   0   0   2   0   0   1   0 185   4   1   0
##         N   0   1   0   0   0   1   0   0   0   1   3   0   4 169   1   0
##         O   1   1   8   3   0   0   1  10   0   3   0   0   4   7 154   4
##         P   0   0   0   4   0  12   0   1   1   4   0   0   0   5   0 151
##         Q   3   2   1   0   8   0  18   2   0   2   0   4   0   0   5   0
##         R   0  14   0   4   0   1   5   8   0   1   7   1   1   4   3   0
##         S   4   3   6   2   7   6   5   0   3   4   0   2   0   0   0   0
##         T   0   0   0   4   3   5   0   1   0   0   1   0   0   0   0   0
##         U   1   0   1   0   0   0   1   6   1   1   0   0   0   1   0   0
##         V   0   1   0   0   0   1   0   0   0   0   1   0   0   0   0   3
##         W   0   1   0   0   0   1   3   3   0   0   1   0   2   4   8   3
##         X   3   1   2   0  16   2   0   1   4   2   7   4   0   0   0   0
##         Y   2   0   0   0   0   3   0   0   0   0   0   5   0   3   0   7
##         Z   0   0   1   0   7   0   1   0   0   4   1   0   0   0   0   0
##
## pred_slow   Q   R   S   T   U   V   W   X   Y   Z
##         A   0   0   9   0   0   0   0   0   0   0
##         B   1  15   7   2   1   0   1   3   0   2
##         C   3   0   0   0   1   0   0   0   0   0
##         D   0   7   3   0   1   0   0   2   2   0
##         E   3   4   5   6   0   0   1   1   0   5
##         F   0   0   2  10   0   1   0   0   6   0
##         G   7   2   2   2   1   0   0   0   0   0
##         H   0   0   4   2   0   2   1   2   0   0
##         I   0   0   3   1   0   0   0   0   1   0
##         J   0   0   0   0   0   0   0   0   0   4
##         K   0   2   0   2   2   0   0  12   0   0
##         L   9   0   2   0   0   0   0   0   0   2
##         M   1   4   0   0  12   1  11   0   0   0
##         N   0   1   0   0   7   4   0   0   0   0
##         O  14   0   0   1   8   1   3  15   1   0
##         P   0   0   0   0   0   5   0   0   1   0
##         Q 118   0   3   0   3   1   0   0   6   2
##         R   1 161   5   0   0   0   1   1   0   2
##         S   5   2 145   3   0   1   0   2   3  13
##         T   0   0   2 165   3   2   0   0   3   3
##         U   0   0   0   6 163   2   0   0   3   0
##         V   0   0   1   0   2 143   0   1  15   0
##         W   0   0   0   0   0   7 152   0   0   0
##         X   0   7   1   8   0   1   0 142   0   2
##         Y   1   0   1   2   2   3   0   5 137   0
##         Z   3   0   5   0   0   0   0   0   0 142
```

```
#Calculate misclassification rate
correct_slow <- sum(diag(conf_slow))
correct_slow
```

```
## [1] 3861
```

```
slow_mis <- (sum(conf_slow) - correct_slow)/sum(conf_slow)
slow_mis
```

```
## [1] 0.2278
```

1. The slower learner yielded a lower misclassification rate of 0.2278.
2. Most of the letter pairs that were difficult to distinguish before become easier to distinguish or remained about the same. The letter pairs that were most difficult to distinguish from one another in the previous model (E and X, H and O, Q ans G, Z and S, and T and Y) all became easier to distinguish. The capacity to distinguish betwen T and Y seemed to improve the most in this model.

Communities and Crime

One last boost

```
#load training data
d <- read.csv("http://andrewpbray.github.io/data/crime-train.csv")

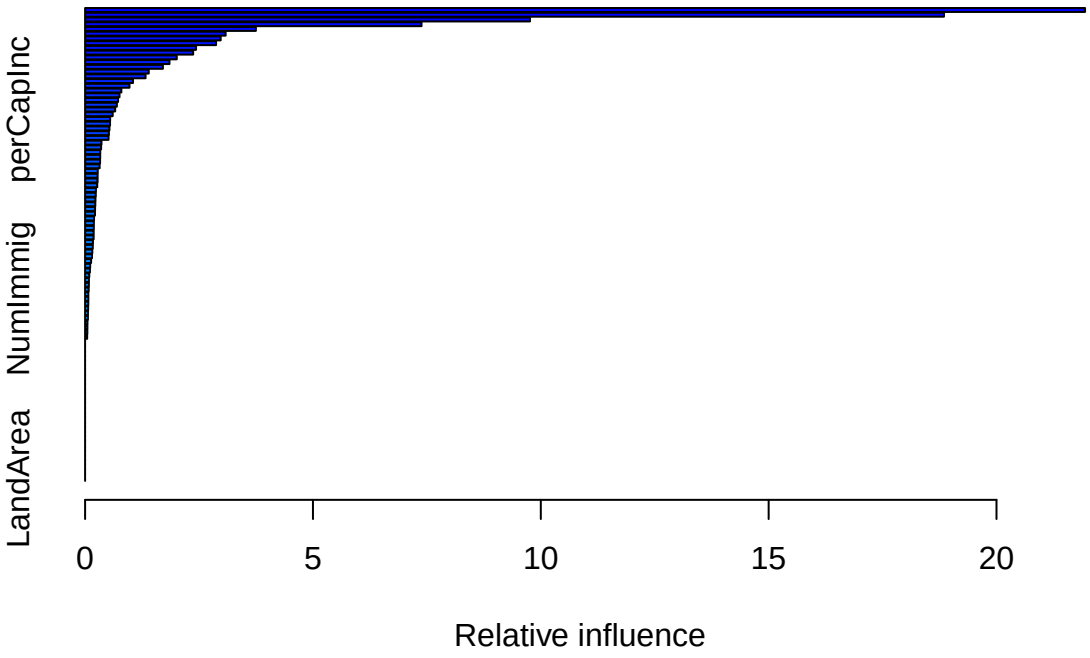
d_cleaned <- data.frame("blank" = rep(0, nrow(d)))
counter <- 1

for(i in 5:ncol(d)){
  if(d[1, i] != "?"){
    d_cleaned[[counter]] <- d[[i]]
    colnames(d_cleaned)[counter] <- colnames(d)[i]
    counter <- counter + 1
  }
}

#load test data
test_data <- read.csv("https://bit.ly/2PYS8Ap")
crime_test <- data.frame("blank" = rep(0, nrow(test_data)))
counter <- 1

for(i in 5:ncol(test_data)){
  if(test_data[1, i] != "?"){
    crime_test[[counter]] <- test_data[[i]]
    colnames(crime_test)[counter] <- colnames(test_data)[i]
    counter <- counter + 1
  }
}
#Build model
set.seed(40)
boost.crime = gbm(ViolentCrimesPerPop ~., data = d_cleaned, distribution = "gaussian", n.trees = 300, i

summary(boost.crime)
```




```
##                                    var     rel.inf
## PctKids2Par                PctKids2Par 21.94376249
## PctIlleg                      PctIlleg 18.84723129
## NumIlleg                      NumIlleg  9.76209302
## racePctWhite              racePctWhite  7.38231049
## PctPersDenseHous      PctPersDenseHous  3.74708310
## NumStreet                    NumStreet  3.08400033
## MalePctDivorce          MalePctDivorce  2.97530387
## PctFam2Par                  PctFam2Par  2.87372730
## FemalePctDiv              FemalePctDiv  2.43449118
## pctWInvInc                  pctWInvInc  2.37113109
## PctHousLess3BR          PctHousLess3BR  2.01114879
## racepctblack              racepctblack  1.85155513
## TotalPctDiv                TotalPctDiv  1.70693230
## PctVacantBoarded      PctVacantBoarded  1.39617727
## racePctHisp                racePctHisp  1.32693795
## PctPopUnderPov          PctPopUnderPov  1.05033812
## PctOccupMgmtProf      PctOccupMgmtProf  0.97365563
## PctLess9thGrade        PctLess9thGrade  0.79535892
## PctUnemployed            PctUnemployed  0.75500702
## RentLowQ                      RentLowQ  0.72314228
## medFamInc                    medFamInc  0.69685138
## perCapInc                    perCapInc  0.65979861
## HousVacant                  HousVacant  0.60535699
## agePct12t21                agePct12t21  0.54941100
## pctWPubAsst                pctWPubAsst  0.54717276
## blackPerCap                blackPerCap  0.53407408
## MedOwnCostPctInc      MedOwnCostPctInc  0.52194038
## PctSameState85          PctSameState85  0.51462562
## PctLargHouseFam        PctLargHouseFam  0.35933991
## pctWSocSec                  pctWSocSec  0.35092789
## MedRent                        MedRent  0.33216610
## RentMedian                  RentMedian  0.33148754
```

```
## PctBSorMore                   PctBSorMore  0.32803655
## OwnOccLowQuart             OwnOccLowQuart  0.31892742
## PctHousNoPhone             PctHousNoPhone  0.27732236
## PopDens                           PopDens  0.27430278
## PctTeen2Par                   PctTeen2Par  0.27407243
## PctEmplProfServ           PctEmplProfServ  0.26649341
## PctWorkMomYoungKids   PctWorkMomYoungKids  0.23694955
## MedRentPctHousInc       MedRentPctHousInc  0.23432758
## PctImmigRec5                 PctImmigRec5  0.22714102
## PctWOFullPlumb             PctWOFullPlumb  0.22430321
## RentHighQ                       RentHighQ  0.21895714
## PctOccupManu                 PctOccupManu  0.21704682
## PctHousOccup                 PctHousOccup  0.19598953
## PctYoungKids2Par         PctYoungKids2Par  0.19212896
## PctNotHSGrad                 PctNotHSGrad  0.19093236
## PctForeignBorn             PctForeignBorn  0.18780610
## PctBornSameState         PctBornSameState  0.18727204
## PctWorkMom                     PctWorkMom  0.17180349
## OwnOccMedVal                 OwnOccMedVal  0.16852292
## OtherPerCap                   OtherPerCap  0.15771872
## NumUnderPov                   NumUnderPov  0.15099079
## medIncome                       medIncome  0.13169955
## pctWWage                         pctWWage  0.11090250
## PctLargHouseOccup       PctLargHouseOccup  0.10618853
## pctWFarmSelf                 pctWFarmSelf  0.09147609
## PctPersOwnOccup           PctPersOwnOccup  0.08377883
## LemasPctOfficDrugUn   LemasPctOfficDrugUn  0.08257018
## PctUsePubTrans             PctUsePubTrans  0.07832274
## PctRecentImmig             PctRecentImmig  0.07134101
## NumImmig                         NumImmig  0.07134046
## MedOwnCostPctIncNoMtg MedOwnCostPctIncNoMtg  0.07000022
## PctEmploy                       PctEmploy  0.06677513
## PctNotSpeakEnglWell   PctNotSpeakEnglWell  0.06265569
## AsianPerCap                   AsianPerCap  0.06163106
## numbUrban                       numbUrban  0.05137516
## HispPerCap                     HispPerCap  0.05048482
## whitePerCap                   whitePerCap  0.04894578
## PersPerRentOccHous     PersPerRentOccHous  0.04492729
## population                     population  0.00000000
## householdsize               householdsize  0.00000000
## racePctAsian                racePctAsian  0.00000000
## agePct12t29                  agePct12t29  0.00000000
## agePct16t24                  agePct16t24  0.00000000
## agePct65up                    agePct65up  0.00000000
## pctUrban                        pctUrban  0.00000000
## pctWRetire                    pctWRetire  0.00000000
## indianPerCap                indianPerCap  0.00000000
## PctEmplManu                  PctEmplManu  0.00000000
## MalePctNevMarr            MalePctNevMarr  0.00000000
## PersPerFam                     PersPerFam  0.00000000
## PctImmigRecent             PctImmigRecent  0.00000000
## PctImmigRec8                 PctImmigRec8  0.00000000
## PctImmigRec10               PctImmigRec10  0.00000000
## PctRecImmig5                 PctRecImmig5  0.00000000
```

```
## PctRecImmig8                 PctRecImmig8  0.00000000
## PctRecImmig10                PctRecImmig10  0.00000000
## PctSpeakEnglOnly           PctSpeakEnglOnly  0.00000000
## PersPerOccupHous           PersPerOccupHous  0.00000000
## PersPerOwnOccHous         PersPerOwnOccHous  0.00000000
## MedNumBR                           MedNumBR  0.00000000
## PctHousOwnOcc                 PctHousOwnOcc  0.00000000
## PctVacMore6Mos               PctVacMore6Mos  0.00000000
## MedYrHousBuilt               MedYrHousBuilt  0.00000000
## OwnOccHiQuart                 OwnOccHiQuart  0.00000000
## NumInShelters                 NumInShelters  0.00000000
## PctSameHouse85               PctSameHouse85  0.00000000
## PctSameCity85                 PctSameCity85  0.00000000
## LandArea                           LandArea  0.00000000
```

```
#Predict rate
yhat.crime = predict(boost.crime, newdata = crime_test, n.trees = 300, type = "response")
#Compute test MSE
mean((yhat.crime - crime_test$ViolentCrimesPerPop)^2)
```

```
## [1] 0.01345545
```

The test MSE of my boosted tree is 0.01345545. This is lower than the test MSEs from my pruned regression tree (0.01544466) and my group's regression model (0.01647594). However, both bagging and the random forest model stil performed better, yielding lower test MSEs of 0.003120125 and 0.003194281 respectively.

Chapter 8 exercises

5.

a) Majority vote approach:

Six estimates of P(Class is Red | X) are greater than 0.5 (0.55, 0.6, 0.6 0.65, 0.7, 0.75), and four estimates of P(Class is Red | X) are less than 0.5 (0.1, 0.15, 0.2, 0.2). Consequently, majority votes indicate that the final classificaion is RED.

```
s = c(0.1, 0.15, 0.2, 0.2, 0.55, 0.6, 0.6, 0.65, 0.7, 0.75)
mean(s)
```

```
## [1] 0.45
```

b) Average probability:

The mean of all the estimates for P(Class is Red | X) is 0.45 which indicates that the final classification is GREEN.

6.

We first use recursive binary splitting to fit a tree to the training data. Recursive binary splitting is an approach that partitions the predictor space intto regions for the best possible minimiization of the RSS. This first single partition entails the consideration of all possible predictors and their possible values before the selection of a cutpoint that generates the lowest RSS. This process – of selecting the predictor and cutpoint that most reduces the RSS within a region – is applied to all subsequent regions until some stopping criterion is met. A common stopping criteria is the reaching of a minimal number of observation at each terminal node.

Next, we apply cost complexity pruning to this resulting large tree to generate a smaller tree with less splits. Cost complexity pruning may enhance the interpretability of our tree and minimize the variance and overfitting tendency of our model. This approach involves the consideration of a sequence of substree as a function of a penalty parameter α that negotiates the tension between the model's fit to the data and

its complexity. In the sequence, each α corresponds to a subtree that minimizes this equation (where T represents the total number of terminal nodes in the tree):

$\sum_{m=i}^{|T|} \sum_{i:x_i E R_m} (y_i - \hat{y}_{R_m})^2 + \alpha |T|$

As α increases from zero, which is the initial tree, the parameter penalizes the complexity of the tree and begins to minimize the number of terminal nodes. Next, we select the optimal α to find its corresponding subtree.

We use K-fold cross validation to select the best α. To do this we split the training data into K folds and perform recursive binary splitting and cost complexity pruning on all but one of the folds which serves as a validation set. We then consider the mean squared error of the predictions of the kth fold as a function of α. After completeing this process for each fold, we choose the α that most reduces the average error.

We then return to the full dataset to find the tree that corresponds to our selected optimal α.