Machine Learning Course Project

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Background Summary

Using devices such as Jawbone Up, Nike FuelBand, and Fitbit it is now possible to collect a large amount of data about personal activity relatively inexpensively. These type of devices are part of the quantified self movement – a group of enthusiasts who take measurements about themselves regularly to improve their health, to find patterns in their behavior, or because they are tech geeks. One thing that people regularly do is quantify how much of a particular activity they do, but they rarely quantify how well they do it. In this project, your goal will be to use data from accelerometers on the belt, forearm, arm, and dumbell of 6 participants. They were asked to perform barbell lifts correctly and incorrectly in 5 different ways. More information is available from the website here: http://web.archive.org/web/20161224072740/http:/groupware.les.inf.puc-rio.br/har (http://web.archive.org/web/20161224072740/http:/groupware.les.inf.puc-rio.br/har) (see the section on the Weight Lifting Exercise Dataset).

Load the Data

```
library(caret)
```

```
## Loading required package: lattice
```

```
## Loading required package: ggplot2
```

```
library(rattle)
```

```
## Loading required package: tibble
```

```
## Loading required package: bitops
```

```
## Rattle: A free graphical interface for data science with R.
## Version 5.4.0 Copyright (c) 2006-2020 Togaware Pty Ltd.
## Type 'rattle()' to shake, rattle, and roll your data.
```

```
library(rpart)
library(rpart.plot)
library(randomForest)
```

```
## randomForest 4.6-14
```

```
## Type rfNews() to see new features/changes/bug fixes.
```

```
##
## Attaching package: 'randomForest'
```

```
## The following object is masked from 'package:rattle':
##
##     importance
```

```
## The following object is masked from 'package:ggplot2':
##
##     margin
```

```
library(gbm)
```

```
## Loaded gbm 2.1.8
```

```
library(e1071)
train_in <- read.csv(url("https://d396qusza40orc.cloudfront.net/predmachlearn/pml-training.csv"), header=TRUE)
valid_in <- read.csv(url("https://d396qusza40orc.cloudfront.net/predmachlearn/pml-testing.csv"), header=TRUE)
```

Explore the Data

```
dim(train_in)
```

```
## [1] 19622   160
```

```
dim(valid_in)
```

```
## [1]  20 160
```

```
str(train_in)
```

```
## 'data.frame':    19622 obs. of  160 variables:
##  $ X                       : int  1 2 3 4 5 6 7 8 9 10 ...
##  $ user_name               : chr  "carlitos" "carlitos" "carlitos" "carlitos" ...
##  $ raw_timestamp_part_1    : int  1323084231 1323084231 1323084231 1323084232 1323084232 1323084232 1323084232 1323084232
1323084232 1323084232 ...
##  $ raw_timestamp_part_2    : int  788290 808298 820366 120339 196328 304277 368296 440390 484323 484434 ...
##  $ cvtd_timestamp          : chr  "05/12/2011 11:23" "05/12/2011 11:23" "05/12/2011 11:23" "05/12/2011 11:23" ...
##  $ new_window              : chr  "no" "no" "no" "no" ...
##  $ num_window              : int  11 11 11 12 12 12 12 12 12 12 ...
##  $ roll_belt               : num  1.41 1.41 1.42 1.48 1.48 1.45 1.42 1.42 1.43 1.45 ...
##  $ pitch_belt              : num  8.07 8.07 8.07 8.05 8.07 8.06 8.09 8.13 8.16 8.17 ...
##  $ yaw_belt                : num  -94.4 -94.4 -94.4 -94.4 -94.4 -94.4 -94.4 -94.4 -94.4 -94.4 ...
##  $ total_accel_belt        : int  3 3 3 3 3 3 3 3 3 3 ...
##  $ kurtosis_roll_belt      : chr  "" "" "" "" ...
##  $ kurtosis_picth_belt     : chr  "" "" "" "" ...
##  $ kurtosis_yaw_belt       : chr  "" "" "" "" ...
##  $ skewness_roll_belt      : chr  "" "" "" "" ...
##  $ skewness_roll_belt.1    : chr  "" "" "" "" ...
##  $ skewness_yaw_belt       : chr  "" "" "" "" ...
##  $ max_roll_belt           : num  NA NA NA NA NA NA NA NA NA NA ...
##  $ max_picth_belt          : int  NA NA NA NA NA NA NA NA NA NA ...
##  $ max_yaw_belt            : chr  "" "" "" "" ...
##  $ min_roll_belt           : num  NA NA NA NA NA NA NA NA NA NA ...
##  $ min_pitch_belt          : int  NA NA NA NA NA NA NA NA NA NA ...
##  $ min_yaw_belt            : chr  "" "" "" "" ...
##  $ amplitude_roll_belt     : num  NA NA NA NA NA NA NA NA NA NA ...
##  $ amplitude_pitch_belt    : int  NA NA NA NA NA NA NA NA NA NA ...
##  $ amplitude_yaw_belt      : chr  "" "" "" "" ...
##  $ var_total_accel_belt    : num  NA NA NA NA NA NA NA NA NA NA ...
##  $ avg_roll_belt           : num  NA NA NA NA NA NA NA NA NA NA ...
##  $ stddev_roll_belt        : num  NA NA NA NA NA NA NA NA NA NA ...
##  $ var_roll_belt           : num  NA NA NA NA NA NA NA NA NA NA ...
##  $ avg_pitch_belt          : num  NA NA NA NA NA NA NA NA NA NA ...
##  $ stddev_pitch_belt       : num  NA NA NA NA NA NA NA NA NA NA ...
##  $ var_pitch_belt          : num  NA NA NA NA NA NA NA NA NA NA ...
##  $ avg_yaw_belt            : num  NA NA NA NA NA NA NA NA NA NA ...
##  $ stddev_yaw_belt         : num  NA NA NA NA NA NA NA NA NA NA ...
##  $ var_yaw_belt            : num  NA NA NA NA NA NA NA NA NA NA ...
##  $ gyros_belt_x            : num  0 0.02 0 0.02 0.02 0.02 0.02 0.02 0.02 0.03 ...
##  $ gyros_belt_y            : num  0 0 0 0 0.02 0 0 0 0 0 ...
##  $ gyros_belt_z            : num  -0.02 -0.02 -0.02 -0.03 -0.02 -0.02 -0.02 -0.02 -0.02 0 ...
##  $ accel_belt_x            : int  -21 -22 -20 -22 -21 -21 -22 -22 -20 -21 ...
##  $ accel_belt_y            : int  4 4 5 3 2 4 3 4 2 4 ...
##  $ accel_belt_z            : int  22 22 23 21 24 21 21 21 24 22 ...
##  $ magnet_belt_x           : int  -3 -7 -2 -6 -6 0 -4 -2 1 -3 ...
##  $ magnet_belt_y           : int  599 608 600 604 600 603 599 603 602 609 ...
##  $ magnet_belt_z           : int  -313 -311 -305 -310 -302 -312 -311 -313 -312 -308 ...
##  $ roll_arm                : num  -128 -128 -128 -128 -128 -128 -128 -128 -128 -128 ...
##  $ pitch_arm               : num  22.5 22.5 22.5 22.1 22.1 22 21.9 21.8 21.7 21.6 ...
##  $ yaw_arm                 : num  -161 -161 -161 -161 -161 -161 -161 -161 -161 -161 ...
##  $ total_accel_arm         : int  34 34 34 34 34 34 34 34 34 34 ...
##  $ var_accel_arm           : num  NA NA NA NA NA NA NA NA NA NA ...
##  $ avg_roll_arm            : num  NA NA NA NA NA NA NA NA NA NA ...
##  $ stddev_roll_arm         : num  NA NA NA NA NA NA NA NA NA NA ...
##  $ var_roll_arm            : num  NA NA NA NA NA NA NA NA NA NA ...
##  $ avg_pitch_arm           : num  NA NA NA NA NA NA NA NA NA NA ...
##  $ stddev_pitch_arm        : num  NA NA NA NA NA NA NA NA NA NA ...
##  $ var_pitch_arm           : num  NA NA NA NA NA NA NA NA NA NA ...
##  $ avg_yaw_arm             : num  NA NA NA NA NA NA NA NA NA NA ...
##  $ stddev_yaw_arm          : num  NA NA NA NA NA NA NA NA NA NA ...
##  $ var_yaw_arm             : num  NA NA NA NA NA NA NA NA NA NA ...
##  $ gyros_arm_x             : num  0 0.02 0.02 0.02 0 0.02 0 0.02 0.02 0.02 ...
##  $ gyros_arm_y             : num  0 -0.02 -0.02 -0.03 -0.03 -0.03 -0.03 -0.02 -0.03 -0.03 ...
##  $ gyros_arm_z             : num  -0.02 -0.02 -0.02 0.02 0 0 0 0 -0.02 -0.02 ...
##  $ accel_arm_x             : int  -288 -290 -289 -289 -289 -289 -289 -289 -288 -288 ...
##  $ accel_arm_y             : int  109 110 110 111 111 111 111 111 109 110 ...
##  $ accel_arm_z             : int  -123 -125 -126 -123 -123 -122 -125 -124 -122 -124 ...
##  $ magnet_arm_x            : int  -368 -369 -368 -372 -374 -369 -373 -372 -369 -376 ...
##  $ magnet_arm_y            : int  337 337 344 344 337 342 336 338 341 334 ...
##  $ magnet_arm_z            : int  516 513 513 512 506 513 509 510 518 516 ...
##  $ kurtosis_roll_arm       : chr  "" "" "" "" ...
##  $ kurtosis_picth_arm      : chr  "" "" "" "" ...
##  $ kurtosis_yaw_arm        : chr  "" "" "" "" ...
##  $ skewness_roll_arm       : chr  "" "" "" "" ...
##  $ skewness_pitch_arm      : chr  "" "" "" "" ...
##  $ skewness_yaw_arm        : chr  "" "" "" "" ...
##  $ max_roll_arm            : num  NA NA NA NA NA NA NA NA NA NA ...
##  $ max_picth_arm           : num  NA NA NA NA NA NA NA NA NA NA ...
##  $ max_yaw_arm             : int  NA NA NA NA NA NA NA NA NA NA ...
##  $ min_roll_arm            : num  NA NA NA NA NA NA NA NA NA NA ...
##  $ min_pitch_arm           : num  NA NA NA NA NA NA NA NA NA NA ...
##  $ min_yaw_arm             : int  NA NA NA NA NA NA NA NA NA NA ...
##  $ amplitude_roll_arm      : num  NA NA NA NA NA NA NA NA NA NA ...
##  $ amplitude_pitch_arm     : num  NA NA NA NA NA NA NA NA NA NA ...
##  $ amplitude_yaw_arm       : int  NA NA NA NA NA NA NA NA NA NA ...
##  $ roll_dumbbell           : num  13.1 13.1 12.9 13.4 13.4 ...
##  $ pitch_dumbbell          : num  -70.5 -70.6 -70.3 -70.4 -70.4 ...
##  $ yaw_dumbbell            : num  -84.9 -84.7 -85.1 -84.9 -84.9 ...
##  $ kurtosis_roll_dumbbell  : chr  "" "" "" "" ...
##  $ kurtosis_picth_dumbbell : chr  "" "" "" "" ...
##  $ kurtosis_yaw_dumbbell   : chr  "" "" "" "" ...
##  $ skewness_roll_dumbbell  : chr  "" "" "" "" ...
##  $ skewness_pitch_dumbbell : chr  "" "" "" "" ...
##  $ skewness_yaw_dumbbell   : chr  "" "" "" "" ...
##  $ max_roll_dumbbell       : num  NA NA NA NA NA NA NA NA NA NA ...
##  $ max_picth_dumbbell      : num  NA NA NA NA NA NA NA NA NA NA ...
##  $ max_yaw_dumbbell        : chr  "" "" "" "" ...
##  $ min_roll_dumbbell       : num  NA NA NA NA NA NA NA NA NA NA ...
```

```
##  $ min_pitch_dumbbell      : num  NA NA NA NA NA NA NA NA NA NA ...
##  $ min_yaw_dumbbell        : chr  "" "" "" "" ...
##  $ amplitude_roll_dumbbell : num  NA NA NA NA NA NA NA NA NA NA ...
##   [list output truncated]
```

The training dataset has 19,622 observations and 160 columns. However, many of the columns have NAs, so they are not useful to our analysis.

Clean the Data

We notice that the NA observations do not help us, so we will remove some of them.

```
trainData<- train_in[, colSums(is.na(train_in)) == 0]
validData <- valid_in[, colSums(is.na(valid_in)) == 0]
dim(trainData)
```

```
## [1] 19622    93
```

```
dim(validData)
```

```
## [1] 20 60
```

We will also remove the first 7 cases from each observation because they do not provide any helpful data.

```
trainData <- trainData[, -c(1:7)]
validData <- validData[, -c(1:7)]
dim(trainData)
```

```
## [1] 19622    86
```

```
dim(validData)
```

```
## [1] 20 53
```

Now lets partition the dataset so that we can perform corss-validation.

```
set.seed(1234)
inTrain <- createDataPartition(trainData$classe, p = 0.7, list = FALSE)
trainData <- trainData[inTrain, ]
testData <- trainData[-inTrain, ]
dim(trainData)
```

```
## [1] 13737    86
```

```
dim(testData)
```

```
## [1] 4123   86
```

Now we need to clean out the Non-Zero Variance in the dataset.

```
NZV <- nearZeroVar(trainData)
trainData <- trainData[, -NZV]
testData  <- testData[, -NZV]
dim(trainData)
```

```
## [1] 13737    53
```

```
dim(testData)
```

```
## [1] 4123   53
```

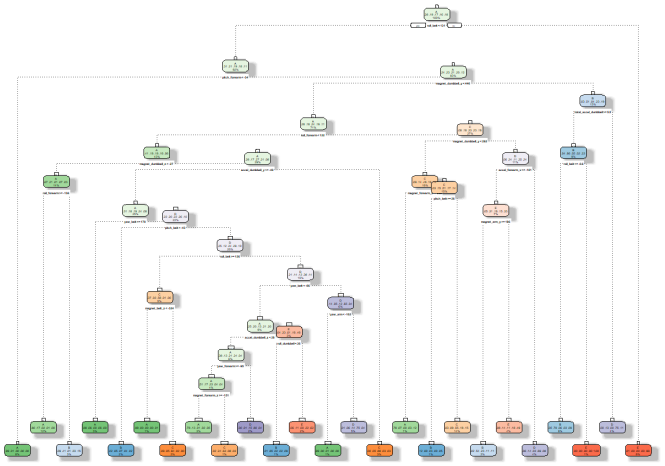
Train the Algorithm

To train the algorithm, we will use 3 techniques and determine the best one. We will then test this best model on the real test dataset at the end.

Train with Classification Tree

```
set.seed(12345)
decisionTreeMod1 <- rpart(classe ~ ., data=trainData, method="class")
fancyRpartPlot(decisionTreeMod1)
```

```
## Warning: labs do not fit even at cex 0.15, there may be some overplotting
```



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```
predictTreeMod1 <- predict(decisionTreeMod1, testData, type = "class")
predictTreeMod1
```

```
##    3    4   10   13   17   25   27   40   41   49   50   53   61
##    A    A    A    A    A    A    A    A    A    A    A    A    A
##   62   63   66   80   87  102  103  107  109  111  112  120  121
##    A    A    A    A    A    A    A    A    A    A    A    A    A
##  125  131  132  133  141  148  153  154  157  163  164  166  167
##    A    A    A    A    A    A    A    A    A    A    A    A    A
##  173  178  180  181  186  199  201  204  207  209  228  239  255
##    A    A    A    A    A    A    A    A    A    A    A    A    A
##  258  259  261  272  273  275  289  292  300  304  306  309  312
##    A    A    A    A    A    A    A    A    A    A    A    A    A
##  316  325  327  331  344  347  363  371  375  376  396  398  399
##    A    A    A    A    A    A    D    A    A    A    A    A    A
##  401  405  409  412  417  419  423  428  429  432  433  442  444
##    A    A    A    A    A    A    A    A    A    A    A    A    B
##  447  452  470  471  472  473  484  490  494  496  501  502  512
##    A    A    A    A    A    A    A    A    A    A    A    A    A
##  522  535  539  540  550  552  554  567  568  569  572  574  578
##    A    A    B    B    A    A    A    A    A    A    A    A    A
##  582  591  594  597  604  610  611  615  627  628  630  632  633
##    A    B    A    A    A    A    A    C    A    A    A    A    A
##  641  648  649  653  654  659  670  677  679  688  696  697  699
##    C    B    B    C    C    B    B    B    B    A    A    A    A
##  703  704  706  708  712  719  726  732  733  735  736  746  748
##    A    A    A    A    A    A    A    A    A    A    A    A    A
##  754  755  757  765  767  773  786  788  792  806  811  818  821
##    A    A    A    A    A    A    A    A    A    A    A    A    A
##  833  835  840  841  855  859  870  872  876  877  882  884  886
##    A    A    A    A    A    A    A    A    A    A    A    A    A
##  902  911  916  917  921  930  931  933  934  945  948  957  959
##    A    A    A    A    A    A    A    C    A    A    A    A    C
##  962  979  984  997 1000 1010 1015 1018 1021 1022 1023 1025 1030
##    C    A    A    C    A    C    C    A    A    C    A    A    C
## 1037 1042 1045 1046 1047 1053 1057 1060 1066 1069 1074 1076 1081
##    A    A    B    B    B    A    A    A    A    E    E    E    E
## 1087 1092 1094 1095 1099 1104 1107 1125 1126 1134 1136 1138 1139
##    C    C    C    A    A    A    A    A    A    A    A    A    A
## 1143 1148 1155 1156 1158 1162 1166 1171 1176 1177 1178 1180 1186
##    A    A    A    A    A    A    A    A    A    A    A    A    D
## 1187 1196 1197 1198 1201 1211 1220 1239 1242 1253 1260 1263 1264
##    D    A    A    A    A    A    A    A    A    A    A    A    A
## 1276 1277 1282 1288 1298 1300 1303 1304 1312 1314 1322 1328 1329
##    A    A    A    A    A    A    A    A    A    A    A    A    A
## 1330 1336 1340 1343 1346 1350 1352 1355 1360 1366 1375 1376 1379
##    A    A    A    A    A    A    A    A    A    A    A    A    A
## 1382 1387 1400 1406 1408 1412 1415 1416 1418 1419 1427 1428 1429
##    A    A    A    A    A    A    A    A    A    A    A    A    A
## 1452 1459 1475 1485 1488 1503 1504 1505 1507 1510 1511 1515 1521
##    A    A    A    A    A    A    A    A    A    A    A    A    A
## 1522 1523 1524 1530 1535 1536 1542 1552 1555 1559 1560 1562 1571
##    A    A    A    A    A    A    A    A    A    A    A    A    A
## 1587 1596 1598 1600 1611 1617 1620 1622 1624 1630 1634 1635 1638
##    A    A    A    A    A    A    A    A    A    A    A    A    A
## 1644 1651 1652 1663 1666 1667 1674 1676 1680 1684 1691 1695 1701
##    A    A    A    A    A    A    A    A    A    A    A    A    A
## 1704 1705 1706 1716 1720 1721 1729 1738 1739 1741 1742 1749 1752
##    A    A    A    A    A    A    A    A    A    A    A    A    A
## 1755 1757 1759 1764 1766 1769 1772 1774 1777 1780 1781 1785 1787
##    A    A    A    A    A    A    A    A    A    A    A    A    A
## 1788 1789 1790 1796 1800 1804 1813 1815 1816 1818 1819 1821 1829
##    A    A    A    A    A    A    A    A    A    A    A    A    A
## 1832 1835 1838 1844 1847 1850 1852 1857 1861 1875 1882 1883 1886
##    A    A    A    A    A    A    A    A    A    A    C    A    A
## 1891 1897 1903 1905 1912 1932 1941 1942 1949 1951 1953 1955 1957
##    A    C    A    A    A    A    E    E    A    A    A    A    A
## 1958 1963 1965 1970 1977 1990 2000 2001 2002 2004 2010 2013 2020
##    A    A    C    C    A    A    E    E    E    E    A    A    A
## 2021 2030 2037 2038 2040 2044 2056 2064 2067 2081 2082 2096 2101
##    A    A    C    C    C    A    A    E    A    C    C    A    A
## 2102 2113 2114 2115 2119 2122 2124 2133 2140 2144 2146 2147 2153
##    A    A    A    A    A    A    A    A    A    A    A    A    A
## 2164 2171 2173 2174 2175 2185 2187 2192 2194 2196 2210 2212 2214
##    E    E    E    E    E    E    C    A    A    A    A    A    A
## 2215 2217 2228 2231 2233 2241 2251 2254 2260 2265 2271 2272 2274
##    A    A    A    A    A    A    A    A    A    A    A    A    A
## 2275 2277 2278 2285 2292 2295 2298 2303 2304 2307 2308 2316 2326
##    A    A    A    A    A    A    A    A    A    A    A    A    A
## 2329 2330 2338 2339 2344 2346 2357 2365 2369 2374 2375 2377 2385
##    A    A    A    A    A    A    A    A    A    A    A    A    A
## 2390 2391 2398 2405 2408 2434 2435 2448 2450 2455 2458 2459 2468
##    A    A    A    A    A    A    A    A    A    A    A    A    A
## 2469 2471 2472 2474 2483 2486 2487 2489 2499 2501 2503 2506 2507
##    A    A    A    A    A    A    A    A    A    A    A    A    A
## 2508 2512 2519 2526 2535 2550 2552 2559 2563 2570 2574 2576 2581
##    A    A    A    A    A    A    A    A    A    A    A    A    A
## 2593 2597 2602 2612 2613 2621 2622 2628 2632 2644 2651 2652 2653
##    A    A    A    A    A    A    A    A    A    A    A    A    A
## 2659 2661 2665 2670 2672 2673 2676 2681 2695 2696 2697 2708 2727
##    A    A    A    A    A    A    A    A    A    A    A    A    A
## 2729 2733 2735 2736 2738 2740 2743 2747 2748 2749 2750 2751 2753
##    A    A    A    A    A    A    A    A    A    A    A    A    A
## 2756 2758 2759 2770 2773 2777 2780 2785 2792 2795 2799 2813 2815
##    A    A    A    A    A    A    A    A    A    A    A    A    A
## 2817 2822 2823 2827 2829 2833 2834 2847 2855 2863 2872 2877 2881
##    A    A    A    A    A    A    A    A    A    A    A    A    A
## 2887 2888 2896 2897 2898 2900 2907 2912 2914 2918 2924 2929 2930
##    A    A    A    A    A    A    A    A    A    A    A    A    A
## 2932 2938 2940 2946 2949 2950 2956 2959 2967 2971 2976 2986 3003
##    A    A    A    A    A    A    A    A    A    A    A    A    A
```

```
##  3007  3013  3016  3024  3025  3034  3038  3040  3049  3061  3067  3070  3078
##     A     A     A     A     A     A     A     A     A     A     A     A     A
##  3079  3080  3081  3085  3086  3103  3104  3120  3126  3136  3139  3148  3151
##     A     A     A     A     A     A     A     A     A     A     A     A     A
##  3156  3165  3171  3184  3205  3207  3217  3218  3219  3220  3222  3224  3225
##     A     A     A     A     A     A     A     A     A     A     A     A     A
##  3232  3240  3242  3244  3252  3256  3265  3268  3270  3275  3280  3281  3293
##     A     A     A     A     A     A     A     A     A     A     A     A     A
##  3312  3313  3324  3327  3343  3346  3347  3348  3359  3364  3368  3371  3372
##     A     A     A     A     A     A     A     A     A     A     A     A     A
##  3377  3383  3402  3405  3406  3408  3419  3420  3428  3430  3432  3438  3443
##     A     A     A     A     A     A     A     A     A     A     A     A     A
##  3444  3445  3447  3449  3454  3456  3461  3462  3468  3469  3472  3477  3482
##     A     A     A     A     A     A     A     A     A     A     A     A     A
##  3485  3487  3491  3500  3501  3504  3505  3509  3529  3537  3546  3552  3555
##     A     A     A     A     A     A     A     A     A     A     A     A     B
##  3557  3558  3562  3563  3576  3583  3584  3585  3589  3593  3613  3625  3628
##     B     B     B     B     A     A     A     A     A     A     B     A     A
##  3636  3639  3646  3649  3650  3656  3661  3662  3669  3670  3692  3693  3695
##     A     A     A     A     B     B     B     B     B     B     A     A     A
##  3700  3703  3705  3707  3708  3713  3717  3719  3725  3732  3733  3735  3736
##     B     B     B     B     B     B     B     B     A     A     A     A     A
##  3744  3748  3751  3753  3757  3760  3763  3765  3776  3782  3785  3793  3801
##     B     D     A     B     A     A     A     A     A     A     A     D     A
##  3803  3813  3818  3819  3827  3830  3835  3836  3837  3839  3846  3847  3849
##     A     A     A     A     A     A     A     A     A     A     A     A     A
##  3851  3856  3859  3864  3866  3867  3869  3872  3873  3876  3883  3885  3887
##     A     A     A     A     A     A     A     A     A     A     D     D     D
##  3892  3895  3906  3923  3927  3937  3938  3939  3948  3956  3960  3968  3972
##     A     A     B     A     D     A     A     A     A     A     A     D     D
##  3977  3984  3985  3991  3993  3997  4000  4001  4002  4011  4015  4025  4026
##     A     A     A     A     A     A     A     A     A     A     A     A     A
##  4033  4038  4041  4043  4046  4048  4051  4052  4055  4056  4057  4060  4061
##     A     A     A     A     A     A     A     A     A     A     A     A     A
##  4077  4079  4083  4090  4097  4103  4116  4134  4136  4137  4139  4140  4141
##     A     A     A     A     A     A     A     A     A     A     A     A     A
##  4148  4149  4153  4156  4158  4163  4168  4169  4178  4181  4191  4192  4194
##     A     A     A     A     A     A     A     A     A     A     A     A     A
##  4204  4206  4210  4214  4215  4217  4219  4223  4232  4239  4241  4242  4243
##     A     A     A     A     A     A     A     A     A     A     A     A     A
##  4250  4252  4253  4258  4261  4263  4264  4267  4271  4276  4281  4289  4296
##     A     A     A     A     A     A     A     A     A     A     A     A     A
##  4297  4299  4301  4307  4314  4316  4318  4329  4332  4343  4350  4352  4355
##     A     A     A     A     A     A     A     A     A     A     A     A     A
##  4357  4364  4366  4368  4370  4372  4398  4405  4406  4411  4415  4419  4420
##     A     A     A     A     A     A     A     A     A     A     A     A     A
##  4422  4428  4443  4445  4449  4451  4457  4462  4466  4473  4475  4477  4486
##     A     A     A     A     A     A     A     A     A     A     A     A     A
##  4489  4492  4493  4495  4509  4513  4515  4528  4529  4547  4548  4549  4550
##     A     A     A     A     A     A     A     A     A     A     A     A     A
##  4551  4557  4561  4564  4568  4569  4570  4571  4585  4586  4587  4592  4605
##     A     A     A     A     A     A     A     A     A     A     A     A     A
##  4608  4610  4611  4613  4618  4620  4632  4635  4637  4638  4640  4653  4657
##     A     A     A     A     A     A     A     A     A     A     A     A     A
##  4658  4671  4672  4680  4684  4686  4689  4692  4703  4706  4713  4715  4721
##     A     A     A     A     A     A     A     A     A     A     A     A     A
##  4724  4741  4745  4751  4756  4757  4765  4771  4772  4775  4776  4793  4799
##     A     A     A     A     A     A     A     A     A     A     A     A     A
##  4807  4811  4821  4824  4825  4830  4832  4836  4845  4850  4864  4883  4887
##     A     A     A     A     A     A     A     A     A     A     A     A     A
##  4893  4897  4902  4905  4914  4929  4930  4935  4939  4942  4946  4955  4958
##     A     A     A     A     A     A     A     A     A     A     A     A     A
##  4961  4963  4979  4983  4991  5000  5001  5004  5011  5016  5017  5019  5022
##     A     A     A     A     A     A     A     A     A     A     A     A     A
##  5024  5025  5033  5034  5035  5040  5044  5046  5054  5057  5058  5064  5068
##     A     A     A     A     A     A     A     A     A     A     A     A     A
##  5072  5084  5096  5098  5106  5111  5114  5116  5127  5131  5139  5145  5151
##     A     A     A     A     A     A     A     A     A     A     A     A     A
##  5156  5159  5160  5162  5163  5165  5167  5170  5173  5178  5184  5186  5190
##     A     A     A     A     A     A     A     A     A     A     A     A     A
##  5194  5208  5213  5224  5225  5226  5228  5230  5238  5239  5240  5241  5262
##     A     A     A     A     A     A     E     E     A     A     A     C     A
##  5281  5282  5283  5287  5300  5308  5309  5314  5315  5316  5317  5318  5330
##     A     A     A     C     A     A     A     A     A     A     A     A     A
##  5341  5344  5345  5349  5359  5366  5374  5384  5387  5400  5402  5404  5409
##     A     A     A     A     A     A     A     A     A     A     A     A     A
##  5416  5419  5426  5428  5438  5439  5440  5451  5454  5465  5466  5471  5475
##     A     A     A     A     A     A     A     A     A     B     B     B     A
##  5478  5487  5488  5495  5502  5504  5505  5506  5513  5514  5517  5529  5537
##     A     A     A     A     A     A     A     A     B     C     A     A     A
##  5538  5542  5556  5557  5573  5575  5577  5578  5583  5588  5598  5606  5607
##     A     A     A     A     A     A     A     A     A     A     B     B     B
##  5610  5611  5614  5620  5623  5644  5649  5653  5654  5655  5657  5666  5668
##     B     B     B     A     A     B     B     B     B     B     B     A     A
##  5671  5677  5683  5695  5702  5715  5718  5730  5733  5734  5735  5736  5748
##     A     A     A     A     A     B     B     A     A     A     A     A     B
##  5749  5754  5755  5756  5761  5762  5763  5778  5780  5795  5800  5814  5815
##     B     B     B     B     B     B     B     B     A     B     C     B     B
##  5822  5827  5832  5837  5846  5849  5850  5857  5859  5860  5864  5865  5871
##     B     A     A     B     B     C     C     C     C     C     B     B     B
##  5872  5881  5882  5883  5890  5891  5893  5903  5904  5917  5922  5925  5936
##     C     C     C     B     B     B     B     A     C     B     B     C     B
##  5938  5941  5946  5948  5949  5951  5952  5960  5969  5970  5977  5978  5979
##     B     B     C     B     B     B     B     B     B     B     C     C     C
##  5983  5995  5998  5999  6005  6013  6027  6029  6032  6037  6039  6040  6041
##     C     C     C     C     B     C     E     E     E     B     B     B     B
##  6044  6052  6054  6056  6068  6069  6070  6087  6090  6100  6101  6103  6111
##     B     B     B     B     B     B     B     C     C     A     A     A     B
##  6114  6118  6119  6121  6123  6135  6140  6143  6146  6149  6152  6155  6162
```

```
##    B    B    B    B    B    B    B    B    C    C    B    B    E
##  6174 6182 6188 6189 6190 6191 6192 6193 6194 6199 6204 6205 6210
##    B    B    B    E    E    D    D    D    D    D    E    C    C
##  6215 6220 6230 6234 6238 6241 6250 6252 6253 6258 6259 6265 6266
##    C    C    B    B    E    D    E    E    C    C    C    C    C
##  6267 6268 6272 6276 6279 6290 6296 6297 6311 6312 6324 6328 6329
##    C    C    C    B    B    B    B    B    C    C    C    C    B
##  6332 6333 6335 6336 6337 6346 6350 6351 6352 6354 6356 6357 6359
##    B    B    B    B    B    B    B    B    B    B    D    D    D
##  6364 6366 6370 6374 6379 6380 6391 6394 6395 6399 6402 6403 6407
##    D    E    C    C    C    C    B    B    B    E    E    E    C
##  6411 6417 6421 6427 6428 6432 6437 6439 6440 6448 6463 6464 6465
##    C    C    C    C    C    B    E    E    B    B    E    E    E
##  6468 6470 6473 6474 6483 6488 6508 6510 6515 6516 6528 6537 6538
##    E    A    A    A    A    A    B    B    B    B    A    A    A
##  6541 6543 6547 6548 6557 6561 6577 6581 6587 6588 6594 6596 6609
##    A    A    A    A    B    B    A    A    B    B    B    B    A
##  6613 6617 6630 6635 6639 6644 6648 6657 6664 6667 6669 6681 6682
##    A    A    A    B    B    A    A    C    C    A    A    B    B
##  6688 6692 6694 6695 6703 6707 6711 6712 6714 6718 6723 6724 6729
##    B    B    B    B    B    B    E    E    B    B    C    C    B
##  6735 6741 6753 6755 6756 6758 6761 6762 6763 6764 6769 6770 6772
##    B    B    C    C    C    B    B    B    B    B    B    B    B
##  6774 6776 6783 6788 6790 6795 6797 6798 6799 6801 6807 6823 6828
##    B    B    C    B    B    B    B    B    B    B    B    B    C
##  6830 6831 6836 6848 6852 6861 6880 6907 6916 6922 6924 6925 6933
##    B    B    B    B    B    E    E    B    D    D    E    E    E
##  6934 6938 6939 6949 6958 6963 6966 6972 6977 6979 6982 6984 6990
##    E    B    B    B    B    B    B    B    B    B    B    B    B
##  6993 6994 6996 7003 7007 7016 7022 7023 7029 7043 7054 7057 7059
##    A    B    B    A    E    E    B    B    B    B    B    B    B
##  7062 7063 7065 7078 7087 7089 7091 7092 7093 7099 7100 7102 7103
##    B    B    B    C    E    B    B    B    B    B    B    B    B
##  7106 7108 7113 7115 7119 7122 7130 7138 7139 7147 7152 7158 7165
##    B    B    B    B    B    C    E    B    B    B    B    B    B
##  7166 7168 7169 7184 7190 7197 7198 7200 7201 7202 7207 7214 7216
##    B    B    B    B    B    B    B    B    B    B    B    B    B
##  7222 7223 7240 7253 7255 7257 7261 7262 7263 7264 7276 7278 7291
##    B    B    B    C    C    B    B    B    B    B    B    B    B
##  7297 7303 7307 7308 7311 7314 7321 7326 7328 7341 7344 7347 7349
##    B    B    B    B    B    B    B    B    B    B    B    B    B
##  7356 7358 7363 7367 7376 7377 7380 7388 7391 7392 7399 7407 7412
##    C    C    C    C    B    B    B    B    B    B    B    B    B
##  7413 7416 7417 7422 7427 7430 7432 7433 7434 7440 7450 7459 7462
##    B    B    B    B    B    B    B    B    B    B    B    B    B
##  7471 7476 7479 7480 7485 7486 7491 7502 7512 7515 7518 7520 7537
##    B    B    B    B    B    B    B    B    B    B    B    B    B
##  7541 7546 7547 7548 7555 7558 7564 7576 7584 7589 7591 7596 7598
##    B    B    B    B    B    B    B    B    B    B    B    B    B
##  7606 7612 7617 7619 7622 7628 7633 7637 7643 7668 7669 7674 7680
##    B    B    B    B    B    B    B    B    B    B    B    B    B
##  7683 7690 7691 7694 7696 7697 7702 7711 7714 7715 7716 7724 7728
##    B    B    B    B    B    B    B    B    B    B    B    B    B
##  7729 7732 7740 7746 7755 7756 7757 7762 7765 7773 7783 7790 7793
##    B    A    B    B    B    B    B    B    B    B    A    C    C
##  7800 7806 7818 7819 7821 7825 7831 7833 7836 7841 7842 7843 7850
##    C    B    B    B    B    B    B    B    B    B    B    B    B
##  7853 7864 7866 7867 7869 7886 7892 7894 7902 7908 7911 7912 7918
##    B    B    B    B    B    B    B    B    B    B    B    B    B
##  7919 7921 7925 7928 7938 7940 7944 7947 7958 7963 7975 7979 7982
##    B    B    B    B    D    D    D    D    A    A    A    A    A
##  7984 7986 7994 7996 7999 8011 8015 8016 8017 8018 8019 8023 8029
##    A    A    A    A    A    A    A    A    A    A    A    A    A
##  8035 8036 8042 8044 8049 8051 8052 8063 8066 8067 8077 8079 8080
##    A    A    A    A    A    A    A    A    A    A    A    B    B
##  8086 8093 8098 8104 8112 8113 8115 8125 8127 8128 8137 8143 8146
##    B    B    B    B    B    B    B    A    A    A    A    A    B
##  8148 8150 8157 8165 8166 8168 8171 8173 8177 8180 8196 8198 8200
##    B    B    B    B    B    B    B    B    B    B    A    B    B
##  8201 8210 8219 8231 8235 8241 8244 8245 8246 8253 8256 8258 8259
##    B    B    B    B    D    D    D    D    D    B    B    B    B
##  8261 8272 8275 8279 8288 8289 8290 8300 8311 8322 8323 8325 8333
##    B    B    B    B    B    B    B    B    B    B    A    B    B
##  8336 8338 8341 8342 8344 8349 8354 8356 8357 8375 8376 8377 8386
##    B    B    B    B    B    B    B    B    B    B    B    B    B
##  8391 8401 8405 8433 8434 8440 8451 8466 8467 8470 8474 8476 8478
##    B    B    B    B    B    B    B    A    A    A    A    A    A
##  8482 8489 8490 8491 8494 8496 8511 8516 8519 8526 8532 8542 8551
##    A    D    D    D    D    D    B    B    B    D    D    D    B
##  8552 8556 8557 8562 8578 8580 8593 8595 8607 8630 8642 8643 8645
##    B    C    C    D    D    B    B    B    D    A    D    D    D
##  8647 8655 8658 8661 8662 8664 8669 8686 8687 8694 8698 8707 8710
##    D    B    B    B    B    B    B    B    B    B    B    B    B
##  8715 8724 8730 8731 8732 8737 8744 8745 8753 8760 8765 8769 8770
##    B    D    D    D    D    D    B    B    B    A    A    B    B
##  8775 8777 8782 8786 8787 8790 8793 8795 8796 8801 8803 8805 8811
##    B    B    B    B    B    B    B    B    B    B    B    B    A
##  8814 8818 8822 8825 8831 8833 8839 8843 8858 8862 8870 8879 8880
##    A    D    A    A    B    B    B    B    B    B    C    B    B
##  8884 8889 8891 8899 8901 8902 8904 8907 8912 8914 8917 8932 8938
##    E    B    B    B    B    B    B    B    C    C    C    B    E
##  8940 8945 8949 8980 8982 8983 8989 8990 8998 9003 9004 9008 9009
##    E    E    E    B    B    B    B    B    B    D    D    D    D
##  9010 9020 9022 9023 9026 9027 9028 9030 9031 9032 9042 9046 9052
##    B    B    B    B    B    B    B    B    D    D    C    C    C
##  9058 9061 9063 9064 9068 9069 9087 9088 9095 9109 9119 9130 9131
##    C    C    C    C    C    C    E    E    E    B    B    A    B
##  9133 9135 9142 9145 9150 9160 9168 9179 9182 9190 9201 9204 9208
##    B    B    A    A    B    A    B    B    B    B    E    D    B
```

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##  9214  9225  9238  9243  9251  9271  9272  9273  9274  9284  9290  9303  9305
##     B     B     B     B     B     B     B     B     C     B     B     C     C
##  9322  9323  9326  9332  9337  9339  9343  9350  9354  9365  9366  9369  9374
##     C     B     B     B     B     B     B     B     C     A     A     B     B
##  9376  9377  9378  9382  9383  9386  9389  9392  9400  9407  9411  9413  9419
##     B     B     C     C     C     C     C     C     C     B     B     B     C
##  9427  9433  9436  9439  9440  9444  9446  9458  9461  9466  9471  9472  9474
##     C     C     C     C     C     C     C     C     C     C     C     C     C
##  9477  9478  9484  9485  9489  9492  9494  9496  9500  9512  9518  9522  9525
##     C     C     C     C     C     C     C     C     C     C     C     C     C
##  9527  9536  9540  9541  9549  9566  9575  9576  9578  9580  9594  9606  9609
##     C     C     C     C     C     C     C     C     C     C     C     C     C
##  9612  9614  9625  9631  9636  9639  9640  9666  9668  9671  9687  9692  9694
##     C     C     C     C     C     C     C     C     C     C     C     C     C
##  9696  9699  9701  9709  9713  9714  9717  9725  9728  9732  9736  9746  9747
##     C     C     C     C     C     C     C     C     C     C     C     C     C
##  9758  9760  9763  9765  9767  9768  9770  9774  9780  9782  9793  9795  9797
##     C     C     C     C     C     C     C     C     C     C     C     C     C
##  9798  9800  9801  9803  9806  9807  9808  9809  9815  9816  9821  9829  9835
##     C     C     C     C     C     C     C     C     C     C     C     C     C
##  9845  9846  9851  9853  9856  9857  9866  9878  9881  9887  9892  9894  9897
##     C     C     C     C     C     C     C     C     C     C     C     C     C
##  9899  9906  9915  9916  9917  9919  9927  9930  9936  9940  9949  9954  9956
##     C     C     C     C     C     C     C     C     C     C     C     C     C
##  9958  9960  9963  9965  9979  9982 10001 10003 10006 10007 10014 10017 10024
##     C     C     C     C     C     C     C     C     C     C     C     C     C
## 10025 10026 10041 10043 10053 10055 10056 10057 10059 10061 10062 10063 10068
##     C     C     C     C     C     C     C     C     C     C     C     C     C
## 10076 10078 10079 10083 10085 10093 10103 10110 10117 10118 10121 10122 10123
##     C     C     C     C     C     C     C     C     C     C     C     C     C
## 10124 10126 10128 10135 10136 10149 10157 10165 10187 10189 10192 10195 10205
##     C     C     C     C     C     C     C     C     C     C     C     C     C
## 10210 10215 10229 10237 10239 10242 10246 10250 10252 10253 10257 10258 10263
##     C     C     C     C     C     C     C     C     C     C     C     C     C
## 10266 10270 10274 10276 10282 10285 10291 10297 10298 10312 10314 10315 10319
##     C     C     C     C     C     C     C     C     C     C     C     C     C
## 10325 10326 10327 10337 10340 10342 10345 10346 10351 10352 10358 10371 10375
##     C     C     C     C     C     C     C     C     C     C     C     C     C
## 10377 10378 10381 10382 10388 10394 10400 10408 10410 10415 10416 10420 10425
##     C     C     C     C     C     C     C     C     C     C     C     C     C
## 10429 10438 10443 10452 10453 10455 10457 10459 10466 10467 10472 10475 10478
##     C     C     C     C     C     C     C     C     C     C     C     C     D
## 10484 10486 10488 10490 10493 10499 10502 10504 10507 10511 10514 10526 10542
##     C     C     C     C     C     C     C     C     C     C     C     C     C
## 10550 10553 10561 10564 10570 10572 10573 10589 10590 10592 10595 10596 10603
##     C     C     C     C     D     D     D     C     C     C     C     C     C
## 10611 10614 10615 10623 10628 10630 10636 10654 10660 10663 10665 10682 10683
##     C     D     D     B     B     B     B     C     C     C     C     C     C
## 10696 10697 10702 10704 10705 10706 10709 10710 10711 10737 10738 10740 10750
##     C     C     C     C     C     C     C     C     C     C     C     C     D
## 10758 10759 10763 10766 10780 10782 10789 10802 10803 10804 10807 10809 10810
##     B     B     C     C     C     C     D     C     C     C     C     C     C
## 10816 10819 10826 10830 10831 10834 10840 10846 10848 10850 10865 10870 10872
##     C     C     D     B     E     E     E     E     C     C     B     B     B
## 10874 10881 10882 10893 10895 10904 10908 10913 10914 10917 10921 10922 10923
##     E     E     E     B     B     E     E     C     C     C     C     C     C
## 10926 10927 10928 10938 10941 10942 10943 10945 10946 10952 10963 10969 10972
##     C     C     C     B     B     B     B     E     E     E     C     B     B
## 10973 10989 10993 10997 10999 11002 11005 11022 11032 11033 11037 11038 11041
##     B     E     C     C     C     C     B     E     C     C     B     B     B
## 11044 11051 11053 11056 11058 11060 11062 11071 11075 11078 11079 11083 11086
##     B     D     D     E     E     A     E     C     C     C     C     C     D
## 11091 11100 11101 11109 11111 11116 11117 11121 11123 11126 11137 11142 11145
##     C     C     C     C     C     C     C     C     E     B     B     B     B
## 11149 11150 11152 11160 11164 11165 11170 11176 11180 11183 11187 11195 11213
##     B     B     B     B     B     B     D     C     C     C     C     C     B
## 11225 11229 11235 11238 11243 11250 11251 11254 11255 11262 11265 11269 11272
##     B     B     B     B     B     B     B     B     B     C     C     C     C
## 11279 11287 11310 11312 11313 11314 11325 11332 11333 11339 11354 11355 11357
##     C     A     C     C     C     C     C     C     C     C     C     C     C
## 11361 11365 11368 11370 11371 11386 11394 11396 11404 11405 11415 11418 11431
##     C     C     A     C     C     C     C     C     C     C     C     C     C
## 11433 11438 11445 11446 11447 11450 11453 11459 11470 11471 11478 11485 11488
##     C     C     C     C     C     C     C     C     C     C     C     C     C
## 11494 11498 11499 11506 11507 11511 11518 11520 11524 11527 11534 11541 11546
##     C     C     C     C     C     C     C     C     C     C     C     C     C
## 11549 11557 11561 11562 11566 11576 11581 11582 11586 11588 11592 11594 11599
##     C     C     C     C     C     C     C     C     C     C     C     C     C
## 11611 11612 11615 11619 11621 11627 11640 11648 11653 11665 11667 11668 11674
##     C     C     C     C     C     C     C     C     C     C     C     C     C
## 11676 11677 11684 11687 11688 11698 11700 11706 11712 11714 11716 11719 11723
##     C     C     C     C     C     C     C     B     B     B     B     B     B
## 11728 11729 11736 11747 11748 11749 11751 11752 11756 11758 11762 11771 11772
##     D     D     D     D     D     D     D     D     D     D     D     D     D
## 11777 11788 11791 11799 11805 11816 11819 11828 11830 11838 11847 11848 11852
##     D     D     D     D     D     D     D     C     C     C     C     C     C
## 11855 11859 11868 11871 11884 11886 11888 11889 11894 11895 11899 11910 11912
##     C     C     C     C     C     C     C     C     D     D     C     C     C
## 11913 11916 11924 11930 11933 11937 11942 11951 11952 11955 11961 11963 11965
##     C     C     D     C     B     B     B     D     D     D     C     C     D
## 11976 11983 11985 11986 11989 11997 12000 12002 12006 12011 12012 12018 12020
##     C     C     C     C     C     C     C     C     C     C     C     C     C
## 12022 12023 12032 12040 12042 12043 12054 12057 12061 12063 12064 12075 12077
##     C     C     C     C     C     C     C     C     C     C     C     C     C
## 12081 12083 12097 12098 12100 12103 12107 12111 12120 12122 12123 12124 12128
##     C     C     C     C     C     C     C     C     C     C     C     C     C
## 12129 12143 12147 12149 12162 12166 12175 12185 12186 12191 12193 12194 12196
##     C     C     C     C     C     C     C     C     C     C     C     C     C
## 12199 12203 12205 12210 12221 12230 12231 12232 12234 12235 12237 12242 12243
```

```
##     C     C     C     C     C     C     C     C     C     C     C     C     C     A
## 12247 12248 12251 12263 12269 12275 12279 12289 12291 12298 12303 12307 12309
##     A     C     A     C     C     C     A     C     C     C     C     C     C     C
## 12311 12312 12313 12315 12325 12327 12329 12336 12340 12351 12356 12358 12363
##     C     C     C     A     A     C     C     C     C     C     C     C     C
## 12366 12367 12370 12378 12382 12388 12393 12396 12400 12409 12412 12413 12418
##     C     C     C     C     C     C     C     C     C     C     C     C     C
## 12420 12421 12445 12449 12454 12456 12460 12471 12472 12474 12482 12484 12486
##     C     C     C     C     C     C     C     C     C     C     C     C     C
## 12488 12489 12491 12499 12504 12507 12511 12512 12516 12523 12534 12537 12548
##     C     C     C     C     C     C     C     C     C     C     B     B     C
## 12556 12558 12559 12566 12573 12579 12582 12587 12591 12592 12599 12603 12608
##     B     C     C     C     C     C     C     C     C     C     C     C     C
## 12611 12616 12618 12620 12625 12633 12643 12645 12646 12665 12670 12673 12676
##     C     C     C     C     C     C     C     C     C     C     C     C     C
## 12681 12686 12688 12698 12699 12700 12711 12714 12720 12722 12723 12728 12731
##     C     C     C     C     C     C     C     C     C     C     C     C     C
## 12735 12736 12740 12749 12751 12773 12777 12779 12783 12784 12789 12798 12800
##     C     C     C     C     D     C     C     C     C     C     C     C     D
## 12818 12819 12821 12831 12834 12835 12838 12853 12855 12870 12872 12875 12881
##     D     D     D     D     D     D     D     D     D     D     D     D     D
## 12885 12900 12901 12905 12906 12909 12910 12916 12919 12922 12924 12931 12932
##     D     D     D     D     D     D     D     D     D     D     D     D     D
## 12935 12937 12943 12949 12952 12953 12954 12964 12972 12977 12978 12981 12990
##     D     D     D     C     C     C     C     C     C     C     C     C     C
## 12992 12993 12994 13003 13008 13010 13026 13027 13028 13029 13032 13035 13039
##     C     C     C     C     A     A     C     C     C     C     C     C     C
## 13049 13061 13064 13065 13066 13068 13070 13077 13084 13089 13100 13102 13104
##     D     C     C     C     C     C     C     C     C     C     C     C     C
## 13131 13134 13137 13138 13147 13148 13153 13168 13170 13176 13177 13182 13184
##     C     C     C     C     C     B     C     B     B     B     B     C     C
## 13189 13194 13206 13207 13216 13218 13220 13224 13225 13233 13236 13237 13248
##     C     C     C     C     C     C     C     C     C     B     B     B     C
## 13249 13253 13254 13268 13273 13276 13286 13291 13293 13294 13297 13303 13308
##     C     C     C     C     C     C     B     B     B     C     C     C     C
## 13309 13311 13313 13316 13318 13319 13333 13338 13341 13346 13351 13353 13356
##     C     B     B     B     B     B     D     D     D     D     D     D     D
## 13358 13361 13377 13392 13400 13405 13406 13407 13410 13412 13420 13425 13428
##     D     D     D     D     D     D     D     D     D     D     D     D     D
## 13430 13437 13438 13446 13449 13451 13457 13462 13463 13473 13474 13475 13476
##     D     D     D     D     D     D     D     D     D     D     D     D     D
## 13484 13489 13493 13494 13503 13505 13507 13512 13515 13516 13521 13522 13525
##     D     D     D     D     D     D     D     D     D     D     D     D     D
## 13535 13536 13555 13556 13563 13564 13568 13569 13572 13580 13583 13585 13589
##     D     D     D     D     D     D     D     D     D     D     D     B     B
## 13593 13594 13600 13609 13615 13620 13626 13631 13638 13644 13648 13665 13667
##     D     B     D     D     D     D     D     C     C     C     D     D     D
## 13674 13678 13680 13683 13687 13695 13696 13699 13700 13703 13705 13707 13716
##     C     C     C     C     C     C     C     D     D     D     D     D     D
## 13718 13719 13722 13724 13729 13730 13744 13750 13757 13768 13774 13778 13793
##     D     D     D     D     D     D     D     D     D     E     C     C     D
## 13814 13828 13836 13838 13839 13843 13846 13851 13863 13869 13881 13885 13889
##     D     E     C     C     C     D     D     A     C     E     E     E     E
## 13890 13893 13895 13900 13901 13917 13920 13921 13922 13927 13933 13934 13935
##     E     C     D     D     D     D     D     C     E     E     E     E     E
## 13938 13959 13966 13971 13979 13981 13982 13986 13999 14003 14009 14012 14013
##     E     D     E     E     E     E     E     E     E     E     D     D     B
## 14014 14017 14018 14020 14023 14026 14028 14036 14053 14055 14057 14065 14069
##     B     B     B     B     E     E     E     D     E     E     E     B     E
## 14071 14080 14081 14082 14083 14084 14090 14093 14096 14097 14099 14100 14103
##     E     E     E     E     B     D     C     C     C     C     B     B     B
## 14110 14111 14120 14125 14126 14132 14146 14149 14152 14158 14161 14166 14167
##     B     D     D     D     E     E     E     B     B     B     B     B     B
## 14174 14180 14183 14190 14193 14195 14199 14201 14206 14224 14235 14239 14241
##     E     E     D     D     D     B     B     B     D     D     D     B     D
## 14242 14249 14252 14257 14264 14266 14268 14276 14279 14283 14293 14300 14306
##     D     D     D     D     D     D     D     B     D     D     D     A     D
## 14307 14310 14312 14318 14336 14340 14345 14347 14348 14349 14351 14352 14356
##     D     D     D     D     D     D     D     D     D     D     D     D     A
## 14360 14363 14365 14366 14378 14391 14397 14398 14400 14401 14413 14426 14428
##     D     D     A     E     C     C     D     D     D     D     D     D     D
## 14433 14435 14444 14447 14449 14453 14457 14460 14463 14469 14474 14481 14487
##     C     D     D     D     D     D     B     B     B     D     D     D     D
## 14489 14491 14492 14498 14499 14500 14503 14505 14506 14514 14523 14527 14531
##     D     D     D     D     D     D     D     D     D     D     D     D     D
## 14534 14535 14540 14542 14543 14547 14548 14562 14564 14568 14572 14581 14584
##     D     D     D     D     D     D     E     E     D     D     D     D     D
## 14588 14596 14606 14609 14618 14629 14630 14651 14654 14658 14667 14671 14685
##     D     D     D     D     D     B     B     D     D     D     D     D     B
## 14687 14689 14693 14697 14701 14722 14726 14727 14731 14733 14735 14737 14738
##     D     D     D     D     D     D     D     D     D     D     D     D     D
## 14739 14751 14767 14769 14770 14772 14776 14794 14812 14814 14816 14818 14821
##     D     D     D     D     D     D     D     D     D     D     D     D     D
## 14823 14838 14839 14844 14862 14870 14876 14879 14880 14893 14901 14911 14916
##     D     D     D     D     D     D     D     D     D     D     D     D     D
## 14925 14928 14931 14936 14942 14945 14948 14950 14967 14968 14969 14972 14973
##     D     D     D     D     D     D     D     D     D     D     D     D     D
## 14978 14979 14984 14985 14989 15009 15014 15015 15016 15030 15040 15049 15050
##     D     D     D     D     D     D     D     D     D     D     D     D     D
## 15052 15059 15060 15064 15069 15071 15074 15075 15076 15087 15090 15094 15096
##     D     D     D     D     D     D     D     D     D     D     D     D     D
## 15097 15099 15100 15111 15120 15122 15123 15124 15127 15128 15131 15148 15158
##     D     D     D     B     B     B     B     A     A     A     A     A     A
## 15159 15160 15171 15172 15184 15185 15186 15187 15190 15197 15198 15205 15206
##     A     A     D     D     D     D     D     D     D     D     D     D     D
## 15211 15212 15214 15216 15219 15222 15227 15230 15231 15241 15243 15263 15269
##     D     D     D     D     D     D     D     D     D     D     D     D     D
## 15271 15272 15277 15285 15286 15291 15292 15294 15297 15298 15299 15304 15305
##     D     D     D     C     C     D     D     D     D     D     D     D     D
```

```
## 15307 15325 15327 15328 15333 15341 15343 15346 15347 15348 15352 15354 15355
##     D     C     C     D     C     D     D     D     D     D     D     D     D
## 15368 15369 15370 15372 15373 15378 15380 15384 15391 15397 15403 15406 15421
##     A     A     D     A     A     A     A     A     D     D     D     D     D
## 15429 15434 15438 15439 15461 15479 15481 15496 15502 15503 15508 15517 15518
##     D     D     D     D     D     D     D     D     D     D     D     D     D
## 15521 15525 15526 15530 15531 15538 15558 15562 15569 15572 15573 15574 15577
##     D     D     D     D     D     D     D     D     D     D     D     D     D
## 15579 15582 15591 15593 15598 15599 15604 15609 15610 15616 15623 15628 15634
##     D     D     D     D     D     D     D     D     D     D     D     D     D
## 15639 15640 15644 15651 15653 15654 15659 15661 15665 15669 15671 15679 15685
##     D     D     D     D     D     D     D     D     D     D     D     D     D
## 15686 15687 15689 15694 15696 15702 15703 15705 15711 15717 15723 15724 15738
##     D     D     D     D     D     D     D     D     D     D     D     D     D
## 15743 15744 15745 15746 15747 15749 15754 15758 15760 15761 15767 15768 15773
##     E     D     D     E     D     D     E     E     E     C     C     C     D
## 15779 15783 15791 15796 15813 15814 15819 15820 15824 15834 15848 15850 15852
##     A     D     D     E     C     C     C     C     C     D     D     C     C
## 15860 15864 15868 15869 15878 15881 15884 15897 15898 15903 15907 15908 15912
##     A     C     C     C     B     B     B     C     C     B     B     B     C
## 15913 15915 15926 15928 15936 15941 15942 15946 15953 15959 15962 15972 15978
##     C     C     C     C     B     C     C     B     C     C     D     D     D
## 15981 15990 15993 15996 15998 15999 16013 16015 16019 16020 16030 16033 16036
##     D     D     B     B     B     B     A     D     D     D     E     E     E
## 16038 16040 16043 16057 16060 16066 16068 16069 16071 16080 16088 16089 16090
##     E     E     B     B     E     E     E     E     E     E     E     E     E
## 16091 16098 16104 16109 16116 16118 16120 16122 16123 16127 16132 16135 16137
##     E     E     E     E     E     E     E     E     E     E     E     E     E
## 16141 16149 16151 16155 16164 16166 16170 16171 16179 16188 16200 16210 16212
##     E     E     E     E     E     E     E     E     E     E     D     D     C
## 16217 16218 16219 16225 16227 16233 16234 16238 16247 16249 16250 16256 16258
##     C     C     C     E     B     B     B     B     E     E     E     E     E
## 16265 16270 16271 16272 16275 16279 16283 16284 16287 16288 16290 16291 16295
##     E     C     C     C     D     A     A     E     E     E     B     B     B
## 16300 16301 16303 16320 16324 16327 16336 16338 16341 16345 16351 16352 16360
##     B     B     B     E     E     E     B     B     B     A     B     B     E
## 16367 16369 16377 16382 16383 16388 16390 16398 16400 16402 16405 16412 16419
##     E     E     E     B     B     E     E     E     B     D     B     B     B
## 16423 16426 16440 16446 16447 16452 16456 16459 16464 16469 16471 16477 16485
##     B     B     E     D     B     B     B     B     B     B     E     E     C
## 16491 16492 16505 16510 16513 16514 16520 16526 16532 16538 16541 16552 16553
##     A     D     C     E     B     B     E     E     A     B     C     E     E
## 16557 16559 16565 16567 16568 16573 16579 16585 16587 16594 16597 16607 16611
##     E     E     E     E     E     E     E     D     E     C     C     E     E
## 16614 16620 16624 16637 16638 16640 16645 16653 16654 16659 16662 16667 16668
##     E     B     E     E     E     E     E     E     C     C     C     E     C
## 16669 16672 16681 16683 16688 16694 16696 16703 16709 16712 16713 16719 16726
##     B     B     C     C     C     C     C     C     C     C     C     C     B
## 16730 16734 16735 16736 16737 16738 16746 16751 16752 16759 16762 16763 16771
##     E     E     E     E     E     E     B     C     C     C     E     E     E
## 16772 16778 16784 16789 16790 16795 16799 16803 16804 16812 16819 16821 16825
##     E     E     E     B     B     B     B     C     C     E     E     E     E
## 16831 16834 16835 16848 16850 16851 16854 16859 16866 16872 16877 16878 16881
##     E     B     B     D     D     D     D     E     E     E     E     E     E
## 16882 16883 16892 16897 16903 16904 16910 16913 16922 16923 16924 16926 16947
##     E     E     D     D     D     D     E     E     E     E     E     E     E
## 16953 16964 16971 16975 16977 16978 16982 17011 17013 17038 17040 17043 17059
##     E     E     E     E     E     E     E     E     E     E     E     E     E
## 17067 17087 17100 17111 17114 17122 17129 17131 17136 17139 17141 17143 17146
##     E     E     A     E     E     E     E     E     E     E     E     E     E
## 17149 17155 17159 17177 17181 17188 17190 17194 17195 17199 17200 17208 17209
##     E     D     B     E     E     E     E     E     E     E     E     E     E
## 17211 17232 17236 17240 17243 17253 17256 17258 17264 17275 17281 17285 17289
##     E     E     E     E     E     E     E     E     E     E     D     D     D
## 17294 17295 17305 17308 17310 17315 17316 17320 17322 17343 17344 17345 17349
##     E     E     E     E     E     E     E     E     E     E     E     E     E
## 17350 17354 17357 17361 17363 17369 17378 17380 17381 17385 17392 17408 17412
##     E     E     E     E     E     E     E     E     E     E     E     E     E
## 17416 17420 17425 17427 17440 17449 17454 17457 17459 17460 17464 17465 17471
##     E     E     E     E     B     D     D     E     E     E     E     E     E
## 17472 17476 17486 17494 17496 17515 17519 17520 17532 17535 17539 17546 17547
##     E     E     E     E     E     A     C     C     C     C     E     B     B
## 17562 17565 17568 17569 17570 17576 17578 17580 17584 17585 17587 17589 17590
##     A     A     E     E     E     E     E     E     E     E     E     E     E
## 17592 17593 17595 17597 17603 17617 17622 17624 17634 17635 17646 17651 17653
##     E     E     E     E     E     E     E     C     C     C     E     B     B
## 17657 17658 17659 17660 17661 17669 17673 17680 17691 17694 17698 17699 17700
##     E     E     E     E     E     E     C     C     E     E     E     E     E
## 17705 17707 17719 17720 17723 17725 17726 17727 17729 17735 17744 17748 17758
##     E     E     C     C     E     E     E     E     E     E     E     E     E
## 17759 17761 17767 17768 17771 17782 17786 17787 17790 17806 17809 17829 17833
##     B     B     E     E     E     E     E     E     E     E     E     E     E
## 17834 17845 17846 17849 17866 17867 17880 17881 17883 17886 17888 17893 17894
##     E     C     C     C     E     E     E     E     E     E     E     E     E
## 17898 17901 17911 17916 17923 17925 17934 17935 17947 17949 17962 17966 17968
##     E     E     E     E     E     E     E     E     E     E     E     D     D
## 17971 17984 17985 17990 17995 18015 18016 18021 18022 18024 18028 18031 18037
##     D     D     D     D     D     E     E     D     D     D     D     E     E
## 18043 18044 18048 18049 18051 18056 18057 18060 18082 18084 18089 18091 18093
##     E     E     E     E     E     E     D     D     C     C     C     C     C
## 18096 18097 18098 18102 18111 18127 18128 18132 18135 18140 18155 18161 18162
##     C     C     C     D     C     B     B     E     C     C     E     B     B
## 18163 18164 18165 18168 18172 18191 18203 18204 18210 18214 18215 18217 18222
##     B     B     B     C     C     E     E     E     C     C     C     C     B
## 18237 18238 18239 18243 18248 18249 18250 18254 18257 18272 18274 18278 18280
##     E     E     E     E     E     E     D     C     B     E     E     E     E
## 18281 18282 18285 18287 18298 18302 18306 18308 18311 18323 18329 18333 18339
##     E     E     E     E     C     B     E     E     B     E     E     E     E
## 18342 18345 18354 18359 18366 18377 18381 18394 18398 18400 18403 18407 18426
```

```
##     E     E     B     B     B     B     E     E     E     E     E     E     E
## 18430 18431 18436 18437 18438 18441 18446 18448 18457 18462 18476 18479 18481
##     E     E     E     E     E     E     E     E     E     E     E     E     E
## 18482 18492 18494 18497 18522 18532 18533 18534 18543 18544 18551 18553 18556
##     E     E     E     E     E     E     E     E     E     E     E     E     E
## 18561 18564 18574 18581 18585 18594 18596 18597 18600 18601 18602 18603 18604
##     E     E     E     E     E     E     E     E     E     E     E     E     E
## 18608 18609 18610 18612 18614 18624 18625 18639 18648 18657 18658 18662 18673
##     E     E     E     E     E     E     E     E     E     E     E     E     E
## 18687 18689 18695 18697 18698 18700 18705 18707 18708 18711 18713 18719 18722
##     E     E     E     E     E     E     E     E     E     E     E     E     E
## 18727 18749 18752 18754 18756 18757 18761 18763 18765 18769 18771 18773 18776
##     E     E     E     E     E     E     E     E     E     E     E     E     E
## 18780 18784 18791 18799 18800 18803 18804 18810 18813 18834 18837 18839 18840
##     E     E     E     E     E     E     E     E     E     E     E     E     E
## 18841 18850 18851 18852 18854 18855 18856 18870 18873 18874 18879 18887 18889
##     E     E     E     E     E     E     E     E     E     E     E     E     E
## 18890 18904 18910 18911 18914 18923 18925 18929 18942 18948 18952 18953 18956
##     E     E     E     E     E     E     E     E     E     E     E     E     E
## 18958 18960 18967 18973 18974 18976 18979 18981 18983 18986 18987 18990 18991
##     E     E     E     E     E     E     E     E     E     E     E     E     E
## 18996 19001 19005 19007 19011 19013 19018 19022 19025 19033 19037 19039 19040
##     C     C     E     E     E     E     E     E     E     E     E     E     E
## 19043 19048 19050 19051 19063 19066 19075 19077 19090 19102 19107 19110 19111
##     E     E     E     E     E     E     E     E     E     E     E     E     E
## 19112 19117 19126 19128 19132 19134 19135 19138 19144 19154 19157 19161 19166
##     E     E     E     E     C     C     C     C     C     E     C     E     C
## 19172 19175 19190 19192 19197 19202 19203 19207 19210 19215 19216 19234 19236
##     E     E     E     E     C     C     C     B     B     E     E     E     E
## 19238 19245 19253 19254 19257 19259 19263 19269 19285 19287 19292 19293 19301
##     D     E     E     E     E     E     C     B     E     E     E     E     E
## 19303 19305 19308 19312 19315 19316 19319 19323 19329 19330 19334 19335 19340
##     E     E     E     E     E     E     E     E     E     E     C     C     C
## 19342 19343 19351 19353 19356 19371 19373 19381 19382 19387 19391 19392 19396
##     E     E     E     E     E     E     E     E     E     E     E     E     E
## 19412 19420 19422 19434 19435 19440 19443 19445 19450 19453 19456 19457 19464
##     E     E     E     E     E     C     C     C     E     E     E     E     E
## 19466 19469 19476 19478 19482 19505 19511 19513 19518 19520 19531 19534 19538
##     E     E     E     E     E     E     E     E     E     E     E     E     E
## 19541 19545 19547 19548 19552 19557 19572 19576 19578 19594 19595 19601 19607
##     C     C     D     E     B     E     D     C     B     B     B     B     B
## 19609 19613
##     E     E
## Levels: A B C D E
```

From this, we can know that our accuracy rate of this model is low: 0.6967 and therfore the out-of-sample-error is about 0.3 which is large.
Train with Random Forest

```
controlRF <- trainControl(method="cv", number=3, verboseIter=FALSE)
modRF1 <- train(classe ~ ., data=trainData, method="rf", trControl=controlRF)
modRF1$finalModel
```

```
##
## Call:
##  randomForest(x = x, y = y, mtry = param$mtry)
##                Type of random forest: classification
##                      Number of trees: 500
## No. of variables tried at each split: 27
##
##         OOB estimate of  error rate: 0.7%
## Confusion matrix:
##      A    B    C    D    E class.error
## A 3902    3    0    0    1 0.001024066
## B   19 2634    5    0    0 0.009029345
## C    0   17 2369   10    0 0.011268781
## D    0    1   26 2224    1 0.012433393
## E    0    2    5    6 2512 0.005148515
```

```
predictRF1 <- predict(modRF1, newdata=testData)
predictRF1
```

```
##    [1] A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A
##   [38] A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A
##   [75] A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A
##  [112] A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A
##  [149] A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A
##  [186] A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A
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## [2295] C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C
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## [2443] C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C
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## [2517] C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C
## [2554] C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C
## [2591] C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C
## [2628] C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C
## [2665] C C C C C C C C C C C C C C C C C C C C C C C C C C D D D D D D D D D D D
## [2702] D D D D D D D D D D D D D D D D D D D D D D D D D D D D D D D D D D D D D
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## [3331] D D D D D D D D D D D D D D D D D D D D D D D D D D D D D D D D E E E E E
## [3368] E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E
## [3405] E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E
## [3442] E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E
## [3479] E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E
## [3516] E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E
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## [3738] E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E
## [3775] E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E
## [3812] E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E
## [3849] E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E
## [3886] E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E
## [3923] E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E
## [3960] E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E
## [3997] E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E
## [4034] E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E
## [4071] E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E
## [4108] E E E E E E E E E E E E E E E E
## Levels: A B C D E
```

From this, we can know that the accuracy rate using the random forest is high (about 1) and the out-of-sample-error is very low (about 0). So we assume this is pretty good, but might be due to overfitting.

Train with Gradient Boosting Method

```
set.seed(12345)
controlGBM <- trainControl(method = "repeatedcv", number = 5, repeats = 1)
modGBM  <- train(classe ~ ., data=trainData, method = "gbm", trControl = controlGBM, verbose = FALSE)
modGBM$finalModel
```

```
## A gradient boosted model with multinomial loss function.
## 150 iterations were performed.
## There were 52 predictors of which 52 had non-zero influence.
```

```
print(modGBM)
```

```
## Stochastic Gradient Boosting
##
## 13737 samples
##    52 predictor
##     5 classes: 'A', 'B', 'C', 'D', 'E'
##
## No pre-processing
## Resampling: Cross-Validated (5 fold, repeated 1 times)
## Summary of sample sizes: 10990, 10990, 10989, 10991, 10988
## Resampling results across tuning parameters:
##
##   interaction.depth  n.trees  Accuracy   Kappa
##   1                   50      0.7521285  0.6858434
##   1                  100      0.8227397  0.7756753
##   1                  150      0.8522224  0.8130469
##   2                   50      0.8564452  0.8181267
##   2                  100      0.9059465  0.8809760
##   2                  150      0.9301168  0.9115592
##   3                   50      0.8969931  0.8695557
##   3                  100      0.9392159  0.9230740
##   3                  150      0.9587251  0.9477728
##
## Tuning parameter 'shrinkage' was held constant at a value of 0.1
##
## Tuning parameter 'n.minobsinnode' was held constant at a value of 10
## Accuracy was used to select the optimal model using the largest value.
## The final values used for the model were n.trees = 150, interaction.depth =
##  3, shrinkage = 0.1 and n.minobsinnode = 10.
```

```
predictGBM <- predict(modGBM, newdata=testData)
predictGBM
```

```
##    [1] A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A
##   [38] A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A
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## [1740] B B B B B B B B B B B B B B B B B B B B B B B B B B B B B B B B B B B B B
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## [1888] B B B B B B B B B B B B B A B B B B B B B B B B B B B B B B B B B B B B B
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## [2258] C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C
## [2295] C C C C C C C C C C C C C C C C C C C C D D D C C C C C C C C C C C C C C
## [2332] C C C C C C C C C E C C C C C C C C C C C B C C B C C C C C C C C C C C C
## [2369] C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C
## [2406] C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C
## [2443] C C C C C C C C C C B C C C C C C C C C C C C C C C C C C C C C D D C C C
## [2480] C C C C C C C C C C C C C C C C C C C C C C C C C C C C C D C C C C C C C
## [2517] C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C
## [2554] C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C
## [2591] C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C
## [2628] C C C C C C C C C E B C C C C C C C C C C C C C C C C C C C C C C C C C C
## [2665] C C C C C C C C C C C C C C C C C C C C C C C C C C D D D D D D D D D D D
## [2702] D D D D D D D D D D D D D D D D D D D D D D D C C C C C D D D D D D D D D
## [2739] D D D D D D D D D D D D D D D D D D D D D D D D D D D D D D D D D D D D D
## [2776] D D D D D D D D D D D D D D D D D D D D D D D D D D D D D D D D D D D D D
## [2813] D D D D D D D D D D D D D D D D D D D D D D D D D D D D D D D D D D D D D
## [2850] D D D D D D D D D D D D D D D D D D C D E D D D D D D D D D D D D D D D D
## [2887] D D D D D D D D D D D D D D D D D D D D D D D D D D D D D D D D D D D D D
## [2924] D D D D D D D D D D D D D D D D D D D D D D D D D D B D B B E E B C D C D
## [2961] D D D D D D D D D D D D D D D D D D D D D D D D D D D D D D D D D D D D D
## [2998] D D D D D D D D D D D D D D D D D D D D D D D D C D D D D D D D D D D D D
## [3035] D D D D D D D D D D D D D D D D D D D D D D D D D D D D D D D D D D D D D
## [3072] D D D D D D D D D D D D D D D D D D D D D D D D D D D D D D D D D D D D D
## [3109] D D D D D D D C D D D D D D D D D D D D D D D D D D D D D D D D D D D D D
## [3146] D D D D D D D D D D D D D D D D D B D E D D D D D D D D D D D D D D D D D
## [3183] D D D D D D D D D D D D D D D D D C D C C D D D D D D D D D C C D C D D D
## [3220] D D D D D D D D D D D D D D D D D D D D D D D D D D D D D D D D D D D D D
## [3257] D D D D D D D D D D D D D D D D D D D D D D D D D D D D D D D D D D D D D
## [3294] D D D D D D D D D D D D D D D D D D D D D D D D D D D D D D D D D D D D D
## [3331] D D D D D D D D D D D D D D D D D D D D D D D D D D D D D D D D E E E E E
## [3368] E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E
## [3405] E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E B E E E E E E
## [3442] E E E E E E E E E E E E E E E E E E E E E E B E E E E E E E E E E E E E E
## [3479] E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E B C C C E
## [3516] E E E E E E D E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E
## [3553] D D D E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E
## [3590] E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E
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## [3627] E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E
## [3664] E E E E E E E E E E E E E E E E E E E E E E E E E E E E A E E E E E E
## [3701] E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E
## [3738] E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E D D E E D
## [3775] D E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E
## [3812] E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E
## [3849] E E E B E B E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E
## [3886] E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E
## [3923] E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E
## [3960] E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E
## [3997] E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E
## [4034] E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E E
## [4071] E E E E E E E E E E E E E E E E B E E E E E E E E E E E E E E E E E E
## [4108] E E E E E E E E E E E E E E E
## Levels: A B C D E
```

The accuracy rate using boosted regression is high (about 0.9736) and the out-of-sample-error- is low (about 0.0264).

Conclusion

Our best model was the random forest model, so we will apply that to the test dataset.

```
Results <- predict(modRF1, newdata=validData)
Results
```

```
##  [1] B A B A A E D B A A B C B A E E A B B B
## Levels: A B C D E
```

This ends this RMD file.