Practical Machine Learning

What should submit

The goal of your project is to predict the manner in which they did the exercise. This is the "classe" variable in the training set. You may use any of the other variables to predict with. You should create a report describing how you built your model, how you used cross validation, what you think the expected out of sample error is, and why you made the choices you did. You will also use your prediction model to predict 20 different test cases.

Background

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 (see the section on the Weight Lifting Exercise Dataset).

Data

The training data for this project are available here: https://d396qusza40orc.cloudfront.net/predmachlearn/pml-training.csv

The test data are available here: https://d396qusza40orc.cloudfront.net/predmachlearn/pml-testing.csv

The data for this project come from this source: http://web.archive.org/web/20161224072740/http:/groupware.les.inf.puc-rio.br/har. If you use the document you create for this class for any purpose please cite them as they have been very generous in allowing their data to be used for this kind of assignment.

Data loading and cleaning

```
# Loading the libraries
library(caret)
```

```
## Warning: package 'caret' was built under R version 3.2.5
```

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

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

```
## Warning: package 'ggplot2' was built under R version 3.2.4
```

```
## Warning: replacing previous import by 'plyr::ddply' when loading 'caret'
```

```
## Warning: replacing previous import by 'tidyr::%>%' when loading 'broom'
```

```
## Warning: replacing previous import by 'tidyr::gather' when loading 'broom'
```

```
## Warning: replacing previous import by 'tidyr::spread' when loading 'broom'
```

```
## Warning: replacing previous import by 'rlang::!!' when loading 'recipes'

## Warning: replacing previous import by 'rlang::expr' when loading 'recipes'

## Warning: replacing previous import by 'rlang::f_lhs' when loading 'recipes'

## Warning: replacing previous import by 'rlang::f_rhs' when loading 'recipes'

## Warning: replacing previous import by 'rlang::is_empty' when loading
## 'recipes'

## Warning: replacing previous import by 'rlang::lang' when loading 'recipes'

## Warning: replacing previous import by 'rlang::na_dbl' when loading
## 'recipes'

## Warning: replacing previous import by 'rlang::names2' when loading
## 'recipes'

## Warning: replacing previous import by 'rlang::quos' when loading 'recipes'

## Warning: replacing previous import by 'rlang::sym' when loading 'recipes'

## Warning: replacing previous import by 'rlang::syms' when loading 'recipes'
```

```r
library(rpart)
```

```
## Warning: package 'rpart' was built under R version 3.2.5
```

```r
library(rpart.plot)
```

```
## Warning: package 'rpart.plot' was built under R version 3.2.5
```

```r
library(randomForest)
```

```
## randomForest 4.6-12

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

##
## Attaching package: 'randomForest'

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

```r
# Loading the dataset from the URL. After the training datased should be divided by two parts: training

data <- read.csv(url("http://d396qusza40orc.cloudfront.net/predmachlearn/pml-training.csv"), na.strings=
data_test <- read.csv(url("http://d396qusza40orc.cloudfront.net/predmachlearn/pml-testing.csv"), na.str

train <- createDataPartition(y = data$classe, p=.80, list = F)
training <- data[train,]
testing <- data[-train,]

# Cleaning the dataset and correction analysis

col_names <- grep("name|timestamp|window|X", colnames(training), value=F)
training_columns <- training[,-col_names]
#select variables with high (over 95%) missing data --> exclude them from the analysis
training_columns[training_columns==""] <- NA
NArate <- apply(training_columns, 2, function(x) sum(is.na(x)))/nrow(training_columns)
```

```
training_columns <- training_columns[!(NArate>0.95)]
summary(training_columns)
```

```
##    roll_belt        pitch_belt          yaw_belt        total_accel_belt
## Min.   :-28.90   Min.   :-55.8000   Min.   :-180.00   Min.   : 0.00
## 1st Qu.:  1.09   1st Qu.:  1.8000   1st Qu.: -88.30   1st Qu.: 3.00
## Median :113.00   Median :  5.3000   Median : -13.10   Median :17.00
## Mean   : 64.37   Mean   :  0.3774   Mean   : -11.54   Mean   :11.31
## 3rd Qu.:123.00   3rd Qu.: 15.1000   3rd Qu.:  12.15   3rd Qu.:18.00
## Max.   :162.00   Max.   : 60.3000   Max.   : 179.00   Max.   :28.00
##   gyros_belt_x        gyros_belt_y        gyros_belt_z
## Min.   :-1.040000   Min.   :-0.64000   Min.   :-1.4600
## 1st Qu.:-0.030000   1st Qu.: 0.00000   1st Qu.:-0.2000
## Median : 0.030000   Median : 0.02000   Median :-0.1000
## Mean   :-0.005956   Mean   : 0.03933   Mean   :-0.1307
## 3rd Qu.: 0.110000   3rd Qu.: 0.11000   3rd Qu.:-0.0200
## Max.   : 2.220000   Max.   : 0.63000   Max.   : 1.6200
##   accel_belt_x       accel_belt_y     accel_belt_z      magnet_belt_x
## Min.   :-83.000   Min.   :-69.00   Min.   :-268.00   Min.   :-49.00
## 1st Qu.:-21.000   1st Qu.:  3.00   1st Qu.:-162.00   1st Qu.:  9.00
## Median :-15.000   Median : 35.00   Median :-152.00   Median : 35.00
## Mean   : -5.714   Mean   : 30.21   Mean   : -72.56   Mean   : 55.53
## 3rd Qu.: -5.000   3rd Qu.: 61.00   3rd Qu.:  27.00   3rd Qu.: 59.00
## Max.   : 85.000   Max.   :150.00   Max.   : 105.00   Max.   :485.00
##  magnet_belt_y    magnet_belt_z       roll_arm        pitch_arm
## Min.   :359.0   Min.   :-623.0   Min.   :-180.00   Min.   :-88.200
## 1st Qu.:581.0   1st Qu.:-375.0   1st Qu.: -31.45   1st Qu.:-25.400
## Median :601.0   Median :-320.0   Median :   0.00   Median :  0.000
## Mean   :593.6   Mean   :-345.7   Mean   :  17.94   Mean   : -4.462
## 3rd Qu.:610.0   3rd Qu.:-306.0   3rd Qu.:  77.10   3rd Qu.: 11.100
## Max.   :673.0   Max.   : 293.0   Max.   : 180.00   Max.   : 88.500
##     yaw_arm         total_accel_arm  gyros_arm_x         gyros_arm_y
## Min.   :-180.0000   Min.   : 1.00   Min.   :-6.37000   Min.   :-3.4000
## 1st Qu.: -43.2000   1st Qu.:17.00   1st Qu.:-1.33000   1st Qu.:-0.7900
## Median :   0.0000   Median :27.00   Median : 0.08000   Median :-0.2400
## Mean   :  -0.6726   Mean   :25.54   Mean   : 0.03704   Mean   :-0.2549
## 3rd Qu.:  46.4000   3rd Qu.:33.00   3rd Qu.: 1.57000   3rd Qu.: 0.1400
## Max.   : 180.0000   Max.   :66.00   Max.   : 4.87000   Max.   : 2.8400
##   gyros_arm_z        accel_arm_x        accel_arm_y        accel_arm_z
## Min.   :-2.3300   Min.   :-404.00   Min.   :-318.00   Min.   :-636.00
## 1st Qu.:-0.0700   1st Qu.:-242.00   1st Qu.: -54.00   1st Qu.:-142.00
## Median : 0.2300   Median : -46.00   Median :  14.00   Median : -47.00
## Mean   : 0.2694   Mean   : -61.08   Mean   :  32.97   Mean   : -71.02
## 3rd Qu.: 0.7200   3rd Qu.:  83.00   3rd Qu.: 140.00   3rd Qu.:  24.00
## Max.   : 3.0200   Max.   : 437.00   Max.   : 308.00   Max.   : 292.00
##   magnet_arm_x      magnet_arm_y      magnet_arm_z     roll_dumbbell
## Min.   :-584.0   Min.   :-392.0   Min.   :-597.0   Min.   :-153.71
## 1st Qu.:-301.0   1st Qu.:  -8.0   1st Qu.: 133.0   1st Qu.: -18.84
## Median : 281.0   Median : 204.0   Median : 446.0   Median :  48.05
## Mean   : 188.7   Mean   : 157.6   Mean   : 307.5   Mean   :  23.85
## 3rd Qu.: 635.0   3rd Qu.: 324.0   3rd Qu.: 545.0   3rd Qu.:  67.60
## Max.   : 780.0   Max.   : 583.0   Max.   : 693.0   Max.   : 153.55
##  pitch_dumbbell    yaw_dumbbell     total_accel_dumbbell
## Min.   :-148.50   Min.   :-148.766   Min.   : 0.00
```

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```
##   1st Qu.: -40.94   1st Qu.: -77.565   1st Qu.: 4.00
##   Median : -21.01   Median :  -3.007   Median :10.00
##   Mean   : -10.74   Mean   :   1.782   Mean   :13.75
##   3rd Qu.:  17.57   3rd Qu.:  79.494   3rd Qu.:20.00
##   Max.   : 149.40   Max.   : 154.223   Max.   :42.00
##   gyros_dumbbell_x  gyros_dumbbell_y   gyros_dumbbell_z  accel_dumbbell_x
##   Min.   :-1.9900   Min.   :-2.10000   Min.   :-2.3800   Min.   :-237.00
##   1st Qu.:-0.0300   1st Qu.:-0.14000   1st Qu.:-0.3100   1st Qu.: -51.00
##   Median : 0.1300   Median : 0.05000   Median :-0.1300   Median :  -9.00
##   Mean   : 0.1723   Mean   : 0.04336   Mean   :-0.1464   Mean   : -28.64
##   3rd Qu.: 0.3500   3rd Qu.: 0.21000   3rd Qu.: 0.0300   3rd Qu.:  11.00
##   Max.   : 2.2200   Max.   : 4.37000   Max.   : 1.8700   Max.   : 235.00
##   accel_dumbbell_y  accel_dumbbell_z  magnet_dumbbell_x magnet_dumbbell_y
##   Min.   :-189.00   Min.   :-334.00   Min.   :-639.0    Min.   :-3600.0
##   1st Qu.:  -8.00   1st Qu.:-142.00   1st Qu.:-535.0    1st Qu.:  231.0
##   Median :  42.00   Median :  -1.00   Median :-479.0    Median :  311.0
##   Mean   :  52.67   Mean   : -37.99   Mean   :-327.6    Mean   :  220.6
##   3rd Qu.: 111.00   3rd Qu.:  39.00   3rd Qu.:-302.5    3rd Qu.:  391.0
##   Max.   : 315.00   Max.   : 318.00   Max.   : 592.0    Max.   :  633.0
##   magnet_dumbbell_z  roll_forearm     pitch_forearm    yaw_forearm
##   Min.   :-262.0    Min.   :-180.00   Min.   :-72.50   Min.   :-180.00
##   1st Qu.: -45.0    1st Qu.:  -0.74   1st Qu.:  0.00   1st Qu.: -68.90
##   Median :  14.0    Median :  22.00   Median :  9.23   Median :   0.00
##   Mean   :  46.2    Mean   :  34.15   Mean   : 10.67   Mean   :  19.18
##   3rd Qu.:  96.0    3rd Qu.: 140.00   3rd Qu.: 28.40   3rd Qu.: 110.00
##   Max.   : 452.0    Max.   : 180.00   Max.   : 89.80   Max.   : 180.00
##   total_accel_forearm gyros_forearm_x   gyros_forearm_y   gyros_forearm_z
##   Min.   : 0.00       Min.   :-4.9500   Min.   :-7.0200   Min.   :-8.090
##   1st Qu.:29.00       1st Qu.:-0.2200   1st Qu.:-1.4700   1st Qu.:-0.180
##   Median :36.00       Median : 0.0500   Median : 0.0300   Median : 0.080
##   Mean   :34.68       Mean   : 0.1569   Mean   : 0.0687   Mean   : 0.142
##   3rd Qu.:41.00       3rd Qu.: 0.5600   3rd Qu.: 1.6500   3rd Qu.: 0.490
##   Max.   :79.00       Max.   : 3.9700   Max.   : 6.1300   Max.   : 4.040
##   accel_forearm_x   accel_forearm_y  accel_forearm_z   magnet_forearm_x
##   Min.   :-498.00   Min.   :-632.0   Min.   :-446.00   Min.   :-1280.0
##   1st Qu.:-178.00   1st Qu.:  55.0   1st Qu.:-182.00   1st Qu.: -614.0
##   Median : -57.00   Median : 200.0   Median : -40.00   Median : -381.0
##   Mean   : -61.58   Mean   : 163.7   Mean   : -54.93   Mean   : -313.1
##   3rd Qu.:  76.00   3rd Qu.: 312.0   3rd Qu.:  26.00   3rd Qu.:  -75.0
##   Max.   : 477.00   Max.   : 591.0   Max.   : 291.00   Max.   :  672.0
##   magnet_forearm_y magnet_forearm_z classe
##   Min.   :-896.0   Min.   :-973     A:4464
##   1st Qu.:   1.0   1st Qu.: 194     B:3038
##   Median : 594.0   Median : 511     C:2738
##   Mean   : 380.4   Mean   : 395     D:2573
##   3rd Qu.: 737.0   3rd Qu.: 654     E:2886
##   Max.   :1480.0   Max.   :1080
```

Principal Components Analysis

```r
pre_process <- preProcess(training_columns[,1:52], method = "pca", thresh = .8) #12 components are requ
pre_process <- preProcess(training_columns[,1:52], method = "pca", thresh = .9) #18 components are requ
```

```r
pre_process <- preProcess(training_columns[,1:52], method = "pca", thresh = .95) #25 components are req
```

```r
pre_process <- preProcess(training_columns[,1:52], method="pca", pcaComp=25)
pre_process$rotation
```

```
##                            PC1         PC2         PC3          PC4
## roll_belt           -0.312900590  0.11198805 -0.084239161  0.0116949061
## pitch_belt          -0.009124697 -0.29351864 -0.074305354 -0.0738635370
## yaw_belt            -0.213107062  0.24053383 -0.027932387  0.0393361243
## total_accel_belt    -0.307938912  0.09196451 -0.108725685 -0.0095424888
## gyros_belt_x         0.082258946  0.19848634  0.211371545  0.0915068813
## gyros_belt_y        -0.113916854  0.20160348  0.084101248  0.0536407624
## gyros_belt_z         0.174795497  0.05696348  0.110640660  0.0386452766
## accel_belt_x        -0.006191699  0.29518379  0.094459003  0.0951872183
## accel_belt_y        -0.317044989  0.02018024 -0.112831313 -0.0120154083
## accel_belt_z         0.320716160 -0.08738982  0.077849572 -0.0282576904
## magnet_belt_x       -0.030027418  0.28837205  0.044489157  0.0896536441
## magnet_belt_y        0.112290053  0.09208251 -0.091719345 -0.2379739307
## magnet_belt_z        0.053428529  0.12306054 -0.072640669 -0.2051725203
## roll_arm             0.070450556 -0.17410974  0.067922082  0.0640804783
## pitch_arm            0.034292429  0.06801494 -0.217506413  0.2201430754
## yaw_arm              0.057701883 -0.11468279  0.016220991  0.1002419499
## total_accel_arm      0.113304574 -0.02965233  0.053315150 -0.0792227011
## gyros_arm_x         -0.014002163  0.05067275  0.001298901  0.0223818879
## gyros_arm_y          0.079350320 -0.07589434 -0.003232440  0.0003297585
## gyros_arm_z         -0.166260075  0.17521299  0.067775724  0.0141442259
## accel_arm_x         -0.154231326 -0.11509131  0.140281479 -0.3034047509
## accel_arm_y          0.275370993 -0.11042313 -0.116275075  0.1345950618
## accel_arm_z         -0.124492801 -0.01230865 -0.261972589  0.2051883874
## magnet_arm_x        -0.089130748 -0.01256656  0.240571407 -0.2843865306
## magnet_arm_y         0.065987739  0.02696799 -0.349410729  0.2495972978
## magnet_arm_z         0.031203438  0.02648517 -0.278824946  0.3207997906
## roll_dumbbell        0.081363126  0.13293480  0.053542495 -0.0838674535
## pitch_dumbbell      -0.101751088 -0.15213157  0.110942990  0.0716504780
## yaw_dumbbell        -0.112450408 -0.27073535  0.013570463  0.0320724546
## total_accel_dumbbell 0.163801656  0.15229013 -0.146046488 -0.1508571376
## gyros_dumbbell_x     0.015992003 -0.03392485 -0.168498156 -0.1273229773
## gyros_dumbbell_y    -0.011455714  0.05442916  0.038081239 -0.0155483275
## gyros_dumbbell_z    -0.048169068  0.01472201  0.126109331  0.1352532198
## accel_dumbbell_x    -0.163995007 -0.14364204  0.157295049  0.1478010389
## accel_dumbbell_y     0.174151764  0.18892793 -0.019732854 -0.1419372283
## accel_dumbbell_z    -0.142141736 -0.25173669  0.086140010  0.1424686566
## magnet_dumbbell_x   -0.155797112 -0.20429599 -0.157422812 -0.0573530249
## magnet_dumbbell_y    0.134448639  0.17985849  0.218947932  0.0433426166
## magnet_dumbbell_z    0.170535005 -0.01135404  0.203005297  0.1951581024
## roll_forearm         0.068393393 -0.04466329 -0.167505707 -0.1702341030
## pitch_forearm       -0.140733688 -0.10850644  0.091469952 -0.0847955041
## yaw_forearm          0.115499312 -0.03004828 -0.134427405 -0.0483446835
## total_accel_forearm -0.006066905  0.09648309 -0.005773486  0.0199895124
## gyros_forearm_x     -0.078955541  0.19406199 -0.076181803  0.0331615772
## gyros_forearm_y     -0.012691605  0.03284180  0.030976378 -0.0315376658
## gyros_forearm_z     -0.013556206  0.07369473  0.055784022  0.0180854237
## accel_forearm_x      0.197140953 -0.07826057 -0.120670504 -0.0104124736
## accel_forearm_y      0.029416072  0.09488831 -0.118917931  0.0090957253
```

```
## accel_forearm_z         -0.035520978  0.03877605  0.238418725  0.2886774140
## magnet_forearm_x         0.105887210 -0.00423921  0.018471560  0.0909644141
## magnet_forearm_y         0.021223255  0.05437893 -0.137476805  0.0037469135
## magnet_forearm_z        -0.041882193  0.10613439 -0.223897597 -0.2931131649
##                                  PC5         PC6         PC7         PC8
## roll_belt               -0.018685934  0.0326496298 -0.081439526  0.032724853
## pitch_belt               0.190236620 -0.1043103749 -0.020445588  0.032168771
## yaw_belt                -0.124535245  0.0784386676 -0.048462394  0.001743073
## total_accel_belt        -0.016565922  0.0369601730 -0.085334744  0.046149344
## gyros_belt_x             0.161387451 -0.0458670151  0.035279680 -0.023506431
## gyros_belt_y             0.131775763 -0.0062173419  0.034467177  0.119749195
## gyros_belt_z             0.102725315 -0.0741434659  0.093412219  0.120217079
## accel_belt_x            -0.179288388  0.0871494636  0.009103474 -0.015672346
## accel_belt_y             0.035683231  0.0074772400 -0.078113340  0.040262530
## accel_belt_z             0.021699665 -0.0249349744  0.086213815 -0.035029511
## magnet_belt_x           -0.200897425  0.0935480180 -0.021905525  0.011209357
## magnet_belt_y            0.179115969 -0.0004766291  0.118170507 -0.106909165
## magnet_belt_z            0.206935910 -0.0460978636  0.144193066 -0.164073517
## roll_arm                -0.224584360  0.0078668377  0.104651764 -0.014368481
## pitch_arm                0.013978778  0.0600982994 -0.018795004 -0.053049949
## yaw_arm                 -0.143198456  0.0109035961  0.072708215  0.032023295
## total_accel_arm         -0.019049000 -0.0770969333 -0.316244713  0.108940374
## gyros_arm_x             -0.007651047 -0.4346914576  0.203208428  0.195418558
## gyros_arm_y              0.020343777  0.4140419571 -0.182580115 -0.186219934
## gyros_arm_z              0.088646527 -0.1722751339  0.027558831  0.116712648
## accel_arm_x             -0.196154499  0.0387708149  0.053108733  0.036096734
## accel_arm_y             -0.010112691  0.0389593780  0.116605207 -0.050464905
## accel_arm_z              0.045193266  0.1191194444  0.209228558 -0.142004929
## magnet_arm_x            -0.091219205  0.0661319354  0.159070004 -0.016971563
## magnet_arm_y             0.101816525  0.0088959474  0.007569327 -0.041062809
## magnet_arm_z             0.139490515  0.0342750730  0.146269464 -0.114831464
## roll_dumbbell           -0.052708562  0.1276259145  0.207199877 -0.234665515
## pitch_dumbbell          -0.089308014  0.0547712833  0.186568670 -0.223573658
## yaw_dumbbell             0.026480853 -0.0777764067  0.035482890 -0.064511800
## total_accel_dumbbell    -0.110742080  0.1151093748 -0.033551113 -0.012332569
## gyros_dumbbell_x        -0.142675265  0.2419017643  0.112239965  0.251008779
## gyros_dumbbell_y         0.101339428 -0.1394636734 -0.233991849 -0.182089631
## gyros_dumbbell_z         0.110139744 -0.1561760893 -0.071160452 -0.235922286
## accel_dumbbell_x        -0.069255185  0.0025771348  0.119681274 -0.156913035
## accel_dumbbell_y        -0.078341412  0.1280732617  0.115886374 -0.145761844
## accel_dumbbell_z        -0.026348093 -0.0770017143  0.030381810 -0.050394426
## magnet_dumbbell_x       -0.201230091  0.0817935041  0.004237948 -0.065814702
## magnet_dumbbell_y        0.202650647 -0.0279284432  0.092276336 -0.070117376
## magnet_dumbbell_z       -0.258784377  0.0713464288  0.035551167  0.035840696
## roll_forearm            -0.117733658 -0.0774275013  0.007690581 -0.007081608
## pitch_forearm            0.086774053  0.1076297164  0.216058280 -0.130742263
## yaw_forearm             -0.244789778 -0.1932470194  0.055937813 -0.061211570
## total_accel_forearm     -0.188651729 -0.0434908722  0.196791608 -0.167647173
## gyros_forearm_x         -0.134936634  0.0935301882  0.174720452  0.156871283
## gyros_forearm_y         -0.037511221 -0.0724010998 -0.321581160 -0.409784399
## gyros_forearm_z         -0.172875243 -0.0536911684 -0.262977295 -0.361583908
## accel_forearm_x         -0.160940299 -0.0378351217 -0.224680468  0.131649905
## accel_forearm_y         -0.351169062 -0.2768719351  0.036944812 -0.076484940
## accel_forearm_z         -0.118500025 -0.0228640353 -0.021190326  0.088452599
```

```
## magnet_forearm_x      -0.013646322  0.1530783989 -0.298219177  0.217109933
## magnet_forearm_y      -0.161803623 -0.4150178060  0.005512637 -0.056823013
## magnet_forearm_z       0.057393827 -0.0853718549 -0.020009588 -0.097463856
##                                 PC9         PC10         PC11         PC12
## roll_belt             -0.0136558047  0.008713796 -0.003481177  0.004436533
## pitch_belt             0.0118690882 -0.013899713 -0.065133011  0.003875260
## yaw_belt              -0.0145764159  0.013094522  0.039417745  0.018563307
## total_accel_belt      -0.0187053722  0.004647305 -0.007663655 -0.002127142
## gyros_belt_x           0.0539137801  0.013960371 -0.012220240  0.076310813
## gyros_belt_y           0.0679531125 -0.016178056  0.050033942  0.278729854
## gyros_belt_z           0.1155971766 -0.119958477  0.096657532  0.243437617
## accel_belt_x           0.0038934235  0.006290727  0.057760716 -0.004541881
## accel_belt_y          -0.0239989652  0.006670015 -0.024126733  0.011529652
## accel_belt_z           0.0023991513 -0.016388952  0.006587283  0.006338551
## magnet_belt_x         -0.0130268443 -0.016939704  0.020568727 -0.067155394
## magnet_belt_y         -0.1035525485  0.001285464  0.048038956  0.180039596
## magnet_belt_z         -0.0830789446  0.053936639  0.010989682  0.210674344
## roll_arm               0.0137904142 -0.070796506  0.085153667 -0.055897719
## pitch_arm             -0.0791549827 -0.124776775 -0.225362273 -0.046177183
## yaw_arm                0.0477310483 -0.071044513  0.215121796 -0.117809246
## total_accel_arm       -0.1570509253  0.048908766 -0.477368396  0.007096719
## gyros_arm_x           -0.3576098648 -0.162646062  0.083839874 -0.175801439
## gyros_arm_y            0.3630270613  0.155990484 -0.108634114  0.156250850
## gyros_arm_z           -0.1568186797 -0.046067705 -0.044161297  0.006550446
## accel_arm_x            0.0303546616 -0.032297216  0.126072958 -0.097422970
## accel_arm_y           -0.0068816695 -0.059040312  0.085822538 -0.100279363
## accel_arm_z            0.0618497263 -0.059161143  0.273105940 -0.036448112
## magnet_arm_x           0.1027210380 -0.051917683  0.279981981 -0.061279403
## magnet_arm_y          -0.1127033496 -0.013080499 -0.033843896 -0.041546074
## magnet_arm_z           0.0165394142 -0.048054929  0.141418175  0.021036796
## roll_dumbbell         -0.2920398253  0.224147435 -0.096571741 -0.039586613
## pitch_dumbbell        -0.3062770866  0.238908421 -0.092632234  0.167312462
## yaw_dumbbell          -0.0653455230  0.105519213 -0.042386470  0.109619126
## total_accel_dumbbell  -0.1050424328 -0.062888131 -0.043495877 -0.231359763
## gyros_dumbbell_x      -0.0828363906 -0.259281645 -0.114403102  0.273006694
## gyros_dumbbell_y       0.0696095903  0.185075234  0.047061881 -0.436881911
## gyros_dumbbell_z       0.0770668808  0.273468017  0.153558640 -0.145935970
## accel_dumbbell_x      -0.1965999365  0.155960202 -0.017347657  0.231317081
## accel_dumbbell_y      -0.2051768508  0.083939349 -0.054461390 -0.115007216
## accel_dumbbell_z      -0.0426620231  0.063924130 -0.036758865  0.118356594
## magnet_dumbbell_x     -0.1823138441  0.042499571 -0.076904690 -0.067929155
## magnet_dumbbell_y     -0.0330858251  0.046674558 -0.024618264  0.105151037
## magnet_dumbbell_z     -0.0444693617 -0.066835728 -0.014081239 -0.033101345
## roll_forearm           0.0111886720  0.007261423  0.156436475  0.149544380
## pitch_forearm          0.0864536985 -0.190245359 -0.006104256 -0.151916493
## yaw_forearm            0.1299761142 -0.020537814 -0.075467876  0.019414965
## total_accel_forearm    0.1086452905  0.004068306 -0.283918634 -0.015985301
## gyros_forearm_x        0.0713708674  0.272764608 -0.008685211 -0.031081990
## gyros_forearm_y       -0.1383881046 -0.379577405  0.126011752  0.127653387
## gyros_forearm_z       -0.1168334019 -0.325449501  0.091820526  0.146986302
## accel_forearm_x       -0.1293381555  0.261779609  0.254435493  0.108040677
## accel_forearm_y        0.1951132652  0.165487007  0.027643622  0.164767075
## accel_forearm_z        0.0257492764 -0.106044988 -0.025627754  0.103574721
## magnet_forearm_x      -0.2965561561  0.229198710  0.350849499  0.130120251
```

```
## magnet_forearm_y      0.2555853862  0.115790525 -0.093775458  0.173964017
## magnet_forearm_z      0.0005126791  0.101216748  0.141074355  0.114000593
##                                PC13         PC14         PC15         PC16
## roll_belt             -0.033600061  0.026163853 -0.012342111  0.086086645
## pitch_belt            -0.151977811 -0.040138286 -0.066378513  0.129920572
## yaw_belt               0.112943949  0.042384881 -0.011003817 -0.004936187
## total_accel_belt      -0.060379886  0.030417748 -0.039639512  0.106073417
## gyros_belt_x          -0.095577124  0.084646329 -0.171928106 -0.118922100
## gyros_belt_y          -0.099329612  0.045052500  0.289702480  0.359663607
## gyros_belt_z          -0.088122863 -0.024134614  0.501989711  0.296520575
## accel_belt_x           0.095233301  0.059300794  0.069067528 -0.110238952
## accel_belt_y          -0.042531071  0.014237133 -0.056823800  0.120754108
## accel_belt_z           0.057021375 -0.031201950 -0.016127049 -0.063558035
## magnet_belt_x          0.066901657  0.081803242 -0.052471957 -0.026133562
## magnet_belt_y          0.305713040 -0.008902814 -0.246150220  0.135564324
## magnet_belt_z          0.375163664  0.043934352 -0.247065407  0.050778426
## roll_arm               0.290963896  0.231001517  0.122558209 -0.070405793
## pitch_arm              0.087208552  0.034144139  0.099546280 -0.157090696
## yaw_arm                0.131928382  0.473865093 -0.175189265  0.498618023
## total_accel_arm        0.144847247  0.231501152  0.106552475  0.041482500
## gyros_arm_x            0.036135892 -0.043835343  0.079177308 -0.050499734
## gyros_arm_y           -0.033136959  0.053635565 -0.040712567  0.062003623
## gyros_arm_z           -0.029277127  0.067020855 -0.120898663  0.026788266
## accel_arm_x            0.024880116 -0.139437338 -0.029049369  0.058043916
## accel_arm_y           -0.039342735 -0.040133959  0.006252899 -0.003577821
## accel_arm_z           -0.064819934 -0.135877106 -0.022239395  0.005041375
## magnet_arm_x          -0.059569194 -0.184677619 -0.049154192 -0.008662731
## magnet_arm_y          -0.002008516  0.071939029  0.004528032  0.084663170
## magnet_arm_z          -0.060535535 -0.057736427 -0.025836631 -0.035279137
## roll_dumbbell         -0.235444542 -0.011387395 -0.001126133  0.102887472
## pitch_dumbbell        -0.108736160  0.061253214  0.086037148 -0.006037710
## yaw_dumbbell          -0.005530949 -0.052008575 -0.076757375  0.077831506
## total_accel_dumbbell  -0.135252513 -0.043057998 -0.078327703  0.221951503
## gyros_dumbbell_x      -0.089227095  0.011080589 -0.055311152 -0.047435200
## gyros_dumbbell_y      -0.201133013  0.030778704  0.129628438  0.065784468
## gyros_dumbbell_z       0.277654495  0.038690843  0.079252254  0.088683912
## accel_dumbbell_x       0.011777219  0.130435038  0.118778018 -0.092949968
## accel_dumbbell_y      -0.213074854  0.075056985 -0.029212044  0.156319379
## accel_dumbbell_z       0.015470895 -0.058144489 -0.078113351  0.087301452
## magnet_dumbbell_x     -0.066292078 -0.036291878  0.024108436  0.148265731
## magnet_dumbbell_y     -0.218996314  0.065022962 -0.055170486 -0.006897056
## magnet_dumbbell_z     -0.085850224 -0.039480527 -0.162376941  0.007752838
## roll_forearm          -0.181791769  0.290589829  0.180751148 -0.200551357
## pitch_forearm         -0.078681936  0.379341682  0.137898411 -0.222504555
## yaw_forearm            0.034274185  0.055976627  0.054870220  0.290100076
## total_accel_forearm    0.198705081 -0.463799853  0.253521982  0.117568874
## gyros_forearm_x        0.177919398  0.080453456  0.069693115 -0.049208427
## gyros_forearm_y       -0.005247626 -0.054045592 -0.002416994  0.007904857
## gyros_forearm_z        0.043363964 -0.015954257  0.068898718  0.008286167
## accel_forearm_x       -0.024773898 -0.083316848  0.008210429 -0.057946276
## accel_forearm_y       -0.054970792  0.046498186 -0.044036413 -0.158937844
## accel_forearm_z       -0.186298847 -0.001615097 -0.297700006  0.087202328
## magnet_forearm_x       0.057428658 -0.124770177  0.046519553  0.011544261
## magnet_forearm_y      -0.218201409  0.003611924 -0.257071773  0.006605718
```

```
## magnet_forearm_z      -0.113960417  0.150537836  0.132414166 -0.108530874
##                                PC17        PC18         PC19         PC20
## roll_belt              -0.026873276  0.021993890  0.0025919294  0.018518363
## pitch_belt             -0.017409671  0.031577860 -0.0027957580  0.003374443
## yaw_belt               -0.027233511 -0.033220682  0.0111401272  0.020135918
## total_accel_belt       -0.028034232  0.022842792  0.0003263903  0.029444261
## gyros_belt_x           -0.029717710  0.111165853  0.2077387535 -0.023300266
## gyros_belt_y           -0.091559235 -0.183568801 -0.1176837849 -0.049687153
## gyros_belt_z           -0.007648191 -0.195731209 -0.1430101735  0.016433618
## accel_belt_x            0.048623456  0.001812900 -0.0081962765  0.017158978
## accel_belt_y           -0.060307165  0.001598234 -0.0166065466  0.011818044
## accel_belt_z           -0.007948632 -0.031725858 -0.0125900269 -0.012753583
## magnet_belt_x          -0.023158387 -0.027924644 -0.0143758302  0.084278418
## magnet_belt_y          -0.252729924 -0.166892402 -0.0728605133 -0.021658126
## magnet_belt_z          -0.159548866 -0.153761422  0.0691029711 -0.011191449
## roll_arm               -0.125586905 -0.247356471  0.1391553101 -0.055961959
## pitch_arm              -0.339404060 -0.186563781 -0.1729247705 -0.216831312
## yaw_arm                 0.274300486  0.135483507  0.1764190809 -0.351248562
## total_accel_arm         0.051015465 -0.066165344 -0.0927706503 -0.026349901
## gyros_arm_x             0.047815705 -0.012199533 -0.0465825433  0.009101959
## gyros_arm_y            -0.030012921 -0.003050383  0.0131977676 -0.004797740
## gyros_arm_z            -0.094251041  0.078490192  0.1492434320 -0.052318562
## accel_arm_x            -0.063771533 -0.070692763 -0.1012485951 -0.009453060
## accel_arm_y             0.051039599 -0.020507410 -0.0288148324  0.011259974
## accel_arm_z            -0.038862366 -0.071092950  0.0094245114  0.017419922
## magnet_arm_x           -0.071051787 -0.058699287 -0.0204811064 -0.034927730
## magnet_arm_y            0.078162485  0.032389427  0.0095290439  0.049107174
## magnet_arm_z           -0.003740198 -0.019406905  0.0319165077  0.026267419
## roll_dumbbell           0.135340968 -0.026400800 -0.0789707968  0.040987459
## pitch_dumbbell          0.043868453 -0.010647769  0.0632014697  0.084085194
## yaw_dumbbell           -0.089812248 -0.069883344 -0.0543954151 -0.162608649
## total_accel_dumbbell   -0.088944129  0.004054091 -0.2209969567 -0.098912370
## gyros_dumbbell_x        0.108455739 -0.036038537  0.0955108336 -0.027481588
## gyros_dumbbell_y       -0.279135408 -0.357374656  0.3843185279 -0.161896244
## gyros_dumbbell_z        0.023409080  0.280739833 -0.5124472628  0.107641735
## accel_dumbbell_x        0.007756825 -0.007772044  0.1671217527  0.057302812
## accel_dumbbell_y        0.007726939 -0.009454934 -0.0792305585  0.022432320
## accel_dumbbell_z       -0.124360616 -0.036560380 -0.0396412878 -0.184773706
## magnet_dumbbell_x      -0.077070142 -0.062300243 -0.1083869846  0.011881627
## magnet_dumbbell_y      -0.014839012  0.090992227  0.1249233713 -0.082575342
## magnet_dumbbell_z      -0.239281435 -0.023714546 -0.1303186271 -0.046606378
## roll_forearm           -0.458480243  0.499052856 -0.0695742458 -0.235826326
## pitch_forearm          -0.002523000 -0.203998598 -0.1058964457  0.159363723
## yaw_forearm            -0.299315368  0.171474111  0.2832588457  0.653891570
## total_accel_forearm     0.008743723  0.251997908  0.2499108625 -0.348729983
## gyros_forearm_x         0.024474685 -0.049027234  0.0301218515 -0.014261051
## gyros_forearm_y         0.101162772  0.030412791  0.0588996370  0.030449871
## gyros_forearm_z         0.089469211 -0.047318842 -0.0198675125 -0.032199368
## accel_forearm_x         0.066674850 -0.155119223  0.0072216112  0.003878217
## accel_forearm_y         0.100695996 -0.196270636 -0.0952731003 -0.098648563
## accel_forearm_z        -0.267943947 -0.008264879 -0.1533316008 -0.017068315
## magnet_forearm_x       -0.105799188  0.002468163  0.1431674222  0.037030633
## magnet_forearm_y        0.147051286 -0.194294748 -0.0830693451  0.000805700
## magnet_forearm_z        0.092739052  0.039368451  0.0132092740 -0.174737251
```

```
##                           PC21         PC22         PC23         PC24
## roll_belt           -0.009551225 -0.0377401074 -0.021184171  0.070881826
## pitch_belt          -0.042061354  0.0406350174 -0.028412381 -0.115049452
## yaw_belt             0.017264379 -0.0577693590  0.009431517  0.134266740
## total_accel_belt    -0.024007746 -0.0357667547 -0.031436848  0.081486788
## gyros_belt_x        -0.055800228  0.1175868740  0.014888673  0.279774919
## gyros_belt_y         0.024615048 -0.0585957577 -0.029229662 -0.060655575
## gyros_belt_z         0.015811024  0.0499298345 -0.012068697  0.128906196
## accel_belt_x         0.052449429 -0.0228864081 -0.004525095  0.124217881
## accel_belt_y        -0.016809325 -0.0290703876 -0.021636408  0.039562890
## accel_belt_z         0.032168939  0.0158938292  0.035500662 -0.063766840
## magnet_belt_x        0.041291320  0.0490998378 -0.049544188  0.248122348
## magnet_belt_y        0.171466632 -0.1726306989  0.090375256 -0.086719174
## magnet_belt_z        0.054172596  0.0017658134  0.042403716  0.141711348
## roll_arm            -0.195251053  0.0355580023 -0.617858264  0.073729859
## pitch_arm           -0.587789821  0.0749141573  0.337320755 -0.076341986
## yaw_arm             -0.139459229 -0.0521784369  0.266817308 -0.022926009
## total_accel_arm      0.179409370 -0.0994285858  0.091902763  0.025632727
## gyros_arm_x          0.055941277  0.0332883891  0.113182040  0.116809581
## gyros_arm_y         -0.033278535 -0.0216908175 -0.055738524 -0.075305571
## gyros_arm_z         -0.165117586 -0.1207067890 -0.370423254 -0.542609974
## accel_arm_x         -0.075592657  0.0080053007  0.150023129  0.001483213
## accel_arm_y          0.161643774 -0.0337197860 -0.003759467 -0.030339413
## accel_arm_z          0.067560579 -0.0468252752  0.006114606  0.006715181
## magnet_arm_x        -0.104495263  0.0005742836  0.145844080 -0.051043294
## magnet_arm_y         0.173335952 -0.0692841174 -0.028401937  0.038370775
## magnet_arm_z         0.042331748  0.0016495168 -0.032766318 -0.045420944
## roll_dumbbell       -0.301048533  0.1985050297  0.005602820  0.044085975
## pitch_dumbbell       0.016046410 -0.0866592796  0.100324834 -0.018780771
## yaw_dumbbell         0.085517678  0.3264806224 -0.162951966  0.195068636
## total_accel_dumbbell 0.082670342  0.0105470554 -0.254008084  0.008353763
## gyros_dumbbell_x    -0.058700958  0.0194619209  0.026006232  0.113129952
## gyros_dumbbell_y     0.155587559  0.0120504364  0.119822046  0.079364979
## gyros_dumbbell_z    -0.121026019 -0.0744180748 -0.056311849  0.003323899
## accel_dumbbell_x     0.116314873 -0.1623447954  0.100087925  0.005325880
## accel_dumbbell_y     0.006587513 -0.0217311175 -0.139526162 -0.008630523
## accel_dumbbell_z    -0.010651468  0.2258159189 -0.101548510  0.117933090
## magnet_dumbbell_x    0.117759765 -0.1033381715 -0.005660155  0.002069575
## magnet_dumbbell_y   -0.072737247 -0.0087415721 -0.034748236 -0.080998887
## magnet_dumbbell_z    0.191842983 -0.1410324428  0.005553919 -0.013151637
## roll_forearm         0.121179374  0.0544210131  0.033271630  0.054161886
## pitch_forearm        0.072655383 -0.2777612282  0.062608302 -0.174696637
## yaw_forearm         -0.152871468  0.0867936398  0.080339706 -0.020828178
## total_accel_forearm  0.033905811 -0.2876603920 -0.018408596 -0.061245270
## gyros_forearm_x      0.264443936  0.4837106150  0.117038509 -0.327060190
## gyros_forearm_y     -0.058569704 -0.0613208272 -0.037649107  0.144026315
## gyros_forearm_z      0.167511566  0.3814542858  0.073439450 -0.386389945
## accel_forearm_x     -0.093648847 -0.1387790688  0.007097151 -0.077774082
## accel_forearm_y     -0.018523748 -0.1468787768  0.022401618 -0.012972642
## accel_forearm_z      0.131592265 -0.1035264961  0.048340063 -0.053988719
## magnet_forearm_x    -0.115175312 -0.1280476130  0.047388035 -0.093989663
## magnet_forearm_y    -0.081634298 -0.0472814983 -0.004172743 -0.031129782
## magnet_forearm_z     0.004361991 -0.0540674459 -0.101692192  0.033471282
##                           PC25
```

```
## roll_belt              0.078314749
## pitch_belt             0.155327532
## yaw_belt              -0.058056134
## total_accel_belt       0.092785015
## gyros_belt_x           0.136417816
## gyros_belt_y           0.121005818
## gyros_belt_z          -0.223856569
## accel_belt_x          -0.132398049
## accel_belt_y           0.140064890
## accel_belt_z          -0.068777983
## magnet_belt_x         -0.210408623
## magnet_belt_y          0.142949458
## magnet_belt_z         -0.154083557
## roll_arm               0.316297768
## pitch_arm              0.027865329
## yaw_arm               -0.044131878
## total_accel_arm       -0.119324177
## gyros_arm_x            0.122270721
## gyros_arm_y           -0.070670088
## gyros_arm_z           -0.519122806
## accel_arm_x           -0.075773172
## accel_arm_y           -0.093339084
## accel_arm_z           -0.108657079
## magnet_arm_x          -0.081313958
## magnet_arm_y          -0.001156377
## magnet_arm_z          -0.074561665
## roll_dumbbell         -0.035233768
## pitch_dumbbell        -0.011150988
## yaw_dumbbell          -0.221441575
## total_accel_dumbbell   0.083648207
## gyros_dumbbell_x      -0.057581965
## gyros_dumbbell_y      -0.092826438
## gyros_dumbbell_z       0.008894980
## accel_dumbbell_x      -0.002898344
## accel_dumbbell_y       0.046880752
## accel_dumbbell_z      -0.068476130
## magnet_dumbbell_x     -0.008151752
## magnet_dumbbell_y      0.212829474
## magnet_dumbbell_z     -0.045849144
## roll_forearm          -0.104051861
## pitch_forearm          0.053938410
## yaw_forearm            0.015224172
## total_accel_forearm    0.130060671
## gyros_forearm_x        0.142732267
## gyros_forearm_y       -0.049707230
## gyros_forearm_z        0.127221181
## accel_forearm_x       -0.011218458
## accel_forearm_y       -0.063301065
## accel_forearm_z        0.228067474
## magnet_forearm_x       0.120557175
## magnet_forearm_y       0.042535205
## magnet_forearm_z       0.181725838
```

```
training_preprocess <- predict(pre_process, training_columns[,1:52])
```

Random Forest

```
fit <- randomForest(training_columns$classe ~ .,data = training_preprocess, do.trace=F)
```

fit
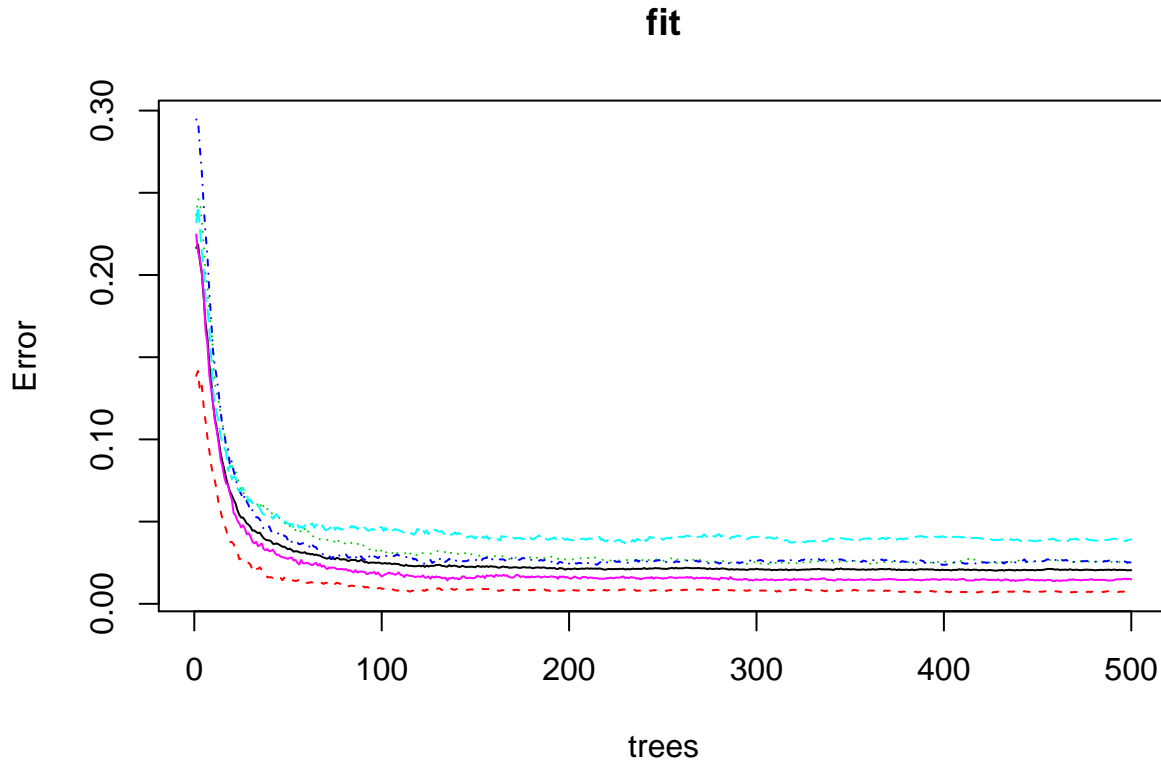
Applying for the testing set and predict for quiz data

```
testing_columns <- testing[,-col_names]
testing_columns[testing_columns==""] <- NA
NArate <- apply(testing_columns, 2, function(x) sum(is.na(x)))/nrow(testing_columns)
testing_columns <- testing_columns[!(NArate>0.95)]
confusionMatrix(testing_columns$classe,predict(fit,predict(pre_process,testing_columns[,1:52])))
```

```
## Confusion Matrix and Statistics
##
##           Reference
## Prediction    A    B    C    D    E
##          A 1108    0    6    0    2
##          B   17  728   13    0    1
##          C    1   10  672    0    1
##          D    0    0   20  623    0
##          E    0    3    4    2  712
##
## Overall Statistics
##
```

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```
##                Accuracy : 0.9796
##                  95% CI : (0.9747, 0.9838)
##     No Information Rate : 0.287
##     P-Value [Acc > NIR] : < 2.2e-16
##
##                   Kappa : 0.9742
##  Mcnemar's Test P-Value : NA
##
## Statistics by Class:
##
##                     Class: A Class: B Class: C Class: D Class: E
## Sensitivity           0.9840   0.9825   0.9399   0.9968   0.9944
## Specificity           0.9971   0.9903   0.9963   0.9939   0.9972
## Pos Pred Value        0.9928   0.9592   0.9825   0.9689   0.9875
## Neg Pred Value        0.9936   0.9959   0.9867   0.9994   0.9988
## Prevalence            0.2870   0.1889   0.1823   0.1593   0.1825
## Detection Rate        0.2824   0.1856   0.1713   0.1588   0.1815
## Detection Prevalence  0.2845   0.1935   0.1744   0.1639   0.1838
## Balanced Accuracy     0.9906   0.9864   0.9681   0.9954   0.9958
```

```r
testing_data_columns <- data_test[,-col_names]
testing_data_columns[testing_data_columns==""] <- NA
NArate <- apply(testing_data_columns, 2, function(x) sum(is.na(x)))/nrow(testing_data_columns)
testing_data_columns <- testing_data_columns[!(NArate>0.95)]
testdataPC <- predict(pre_process,testing_data_columns[,1:52])
testing_data_columns$classe <- predict(fit,testdataPC)
testing_data_columns$classe
```

```
##  [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
```