# Prediction Assignment Machine Learning

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## R Markdown

## Executive Summary

**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, the goal is to analyze data from accelerometers on the belt, forearm, arm, and dumbell of six participants. They were asked to perform barbell lifts correctly and incorrectly in five different ways. For more information see the "Weight Lifting Exercises Dataset" in the following location:**

**http://groupware.les.inf.puc-rio.br/har**

**Specifically, the goal of this machine learning exercise is to predict the manner in which the participants did the exercise-that is, to predict the "classe" variable found in the training set. The prediction model will then be used to predict twenty different test cases, as provided in the testing dataset.**

**Data Processing and Analysis**

**The training and testing datasets used in the analysis may be found as follows:**

**Training dataset:**

**https://d396qusza40orc.cloudfront.net/predmachlearn/pml-training.csv**

**Testing dataset:**

**https://d396qusza40orc.cloudfront.net/predmachlearn/pml-testing.csv**

**We begin by loading the required libraries and reading in the training and testing datasets, assigning missing values to entries that are currently 'NA' or blank:**

## Goal of assignment

**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.**

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

```
## Warning: package 'caret' was built under R version 3.4.3
```

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

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

```
## Warning: package 'ggplot2' was built under R version 3.4.3
```

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

```
## Warning: package 'rpart.plot' was built under R version 3.4.2
```

```r
library(randomForest)
```

```
## Warning: package 'randomForest' was built under R version 3.4.3
```

```
## 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
```

## DATA ACQUISITION

**Loading the dataset from the URL. After the training datased should be divided by two parts: training and testing sets. 80% of the dataset is used for modeling, 20% of the dataset is used for the quiz result.**

```r
data <- read.csv("pml-training.csv", na.strings=c("NA","#DIV/0!",""))
data_test <- read.csv("pml-testing.csv", na.strings=c("NA","#DIV/0!",""))



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.:  1.10   1st Qu.:  1.8000   1st Qu.: -88.30   1st Qu.: 3.00
```

```
##  Median :114.00   Median :  5.3300   Median : -12.60   Median :17.00
##  Mean   : 64.62   Mean   :  0.3568   Mean   : -11.08   Mean   :11.35
##  3rd Qu.:123.00   3rd Qu.: 15.1000   3rd Qu.:  13.20   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.:-0.050000   1st Qu.: 0.00000   1st Qu.:-0.2000
##  Median : 0.030000   Median : 0.02000   Median :-0.1000
##  Mean   :-0.006174   Mean   : 0.03954   Mean   :-0.1305
##  3rd Qu.: 0.110000   3rd Qu.: 0.11000   3rd Qu.:-0.0200
##  Max.   : 2.220000   Max.   : 0.61000   Max.   : 1.6200
##   accel_belt_x       accel_belt_y     accel_belt_z     magnet_belt_x
##  Min.   :-120.000   Min.   :-69.00   Min.   :-269.00   Min.   :-49.00
##  1st Qu.: -21.000   1st Qu.:  3.00   1st Qu.:-162.00   1st Qu.:  9.00
##  Median : -15.000   Median : 36.00   Median :-153.00   Median : 34.00
##  Mean   :  -5.659   Mean   : 30.29   Mean   : -72.96   Mean   : 55.45
##  3rd Qu.:  -5.000   3rd Qu.: 61.00   3rd Qu.:  27.00   3rd Qu.: 59.00
##  Max.   :  85.000   Max.   :164.00   Max.   : 105.00   Max.   :485.00
##  magnet_belt_y   magnet_belt_z       roll_arm         pitch_arm
##  Min.   :354.0   Min.   :-623.0   Min.   :-180.00   Min.   :-88.800
##  1st Qu.:581.0   1st Qu.:-375.0   1st Qu.: -32.20   1st Qu.:-25.900
##  Median :601.0   Median :-319.0   Median :   0.00   Median :  0.000
##  Mean   :593.6   Mean   :-345.4   Mean   :  17.76   Mean   : -4.727
##  3rd Qu.:610.0   3rd Qu.:-306.0   3rd Qu.:  77.10   3rd Qu.: 11.300
##  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.   :-3.4400
##  1st Qu.: -43.0500   1st Qu.:17.00   1st Qu.:-1.36000   1st Qu.:-0.8000
##  Median :   0.0000   Median :27.00   Median : 0.08000   Median :-0.2400
##  Mean   :  -0.5326   Mean   :25.47   Mean   : 0.03318   Mean   :-0.2554
##  3rd Qu.:  46.5000   3rd Qu.:33.00   3rd Qu.: 1.56000   3rd Qu.: 0.1600
##  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.   :-2.2800   Min.   :-404.00   Min.   :-318.00   Min.   :-636.00
##  1st Qu.:-0.0800   1st Qu.:-241.00   1st Qu.: -54.00   1st Qu.:-142.00
##  Median : 0.2300   Median : -43.00   Median :  13.00   Median : -45.00
##  Mean   : 0.2695   Mean   : -59.67   Mean   :  32.29   Mean   : -70.65
##  3rd Qu.: 0.7200   3rd Qu.:  84.00   3rd Qu.: 138.00   3rd Qu.:  24.00
##  Max.   : 3.0200   Max.   : 435.00   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.:-299.0   1st Qu.:  -9.0   1st Qu.: 131.0   1st Qu.: -19.75
##  Median : 289.0   Median : 200.0   Median : 444.0   Median :  47.81
##  Mean   : 192.8   Mean   : 156.3   Mean   : 306.8   Mean   :  23.14
##  3rd Qu.: 639.0   3rd Qu.: 323.0   3rd Qu.: 545.0   3rd Qu.:  67.18
##  Max.   : 780.0   Max.   : 583.0   Max.   : 694.0   Max.   : 153.55
##  pitch_dumbbell     yaw_dumbbell      total_accel_dumbbell
##  Min.   :-149.59   Min.   :-150.871   Min.   : 0.00
##  1st Qu.: -40.86   1st Qu.: -77.644   1st Qu.: 4.00
##  Median : -20.89   Median :  -3.031   Median :10.00
##  Mean   : -10.84   Mean   :   1.951   Mean   :13.64
##  3rd Qu.:  17.55   3rd Qu.:  80.630   3rd Qu.:19.00
##  Max.   : 149.40   Max.   : 154.952   Max.   :58.00
##  gyros_dumbbell_x    gyros_dumbbell_y   gyros_dumbbell_z
```

```
##  Min.   :-204.0000   Min.   :-2.10000   Min.   : -2.3800
##  1st Qu.:  -0.0300   1st Qu.:-0.14000   1st Qu.: -0.3100
##  Median :   0.1300   Median : 0.03000   Median : -0.1300
##  Mean   :   0.1596   Mean   : 0.04612   Mean   : -0.1268
##  3rd Qu.:   0.3500   3rd Qu.: 0.21000   3rd Qu.:  0.0300
##  Max.   :   2.2200   Max.   :52.00000   Max.   :317.0000
##  accel_dumbbell_x accel_dumbbell_y  accel_dumbbell_z  magnet_dumbbell_x
##  Min.   :-419.0   Min.   :-189.00   Min.   :-334.00   Min.   :-643.0
##  1st Qu.: -50.0   1st Qu.:  -9.00   1st Qu.:-141.00   1st Qu.:-535.5
##  Median :  -8.0   Median :  40.00   Median :  -1.00   Median :-479.0
##  Mean   : -28.6   Mean   :  51.82   Mean   : -38.11   Mean   :-328.5
##  3rd Qu.:  11.0   3rd Qu.: 110.00   3rd Qu.:  38.00   3rd Qu.:-307.0
##  Max.   : 235.0   Max.   : 302.00   Max.   : 318.00   Max.   : 592.0
##  magnet_dumbbell_y magnet_dumbbell_z  roll_forearm      pitch_forearm
##  Min.   :-3600     Min.   :-250.00   Min.   :-180.000   Min.   :-72.50
##  1st Qu.:  231     1st Qu.: -46.00   1st Qu.:  -0.655   1st Qu.:  0.00
##  Median :  309     Median :  12.00   Median :  22.100   Median :  9.35
##  Mean   :  219     Mean   :  45.23   Mean   :  34.100   Mean   : 10.72
##  3rd Qu.:  389     3rd Qu.:  95.00   3rd Qu.: 140.000   3rd Qu.: 28.40
##  Max.   :  633     Max.   : 451.00   Max.   : 180.000   Max.   : 89.80
##   yaw_forearm      total_accel_forearm gyros_forearm_x
##  Min.   :-180.00   Min.   :  0.00      Min.   :-22.000
##  1st Qu.: -68.30   1st Qu.: 29.00      1st Qu.: -0.220
##  Median :   0.00   Median : 36.00      Median :  0.050
##  Mean   :  19.01   Mean   : 34.68      Mean   :  0.158
##  3rd Qu.: 110.00   3rd Qu.: 41.00      3rd Qu.:  0.560
##  Max.   : 180.00   Max.   :108.00      Max.   :  3.970
##  gyros_forearm_y     gyros_forearm_z    accel_forearm_x   accel_forearm_y
##  Min.   : -7.02000   Min.   : -8.0900   Min.   :-496.00   Min.   :-585.0
##  1st Qu.: -1.48000   1st Qu.: -0.1800   1st Qu.:-178.00   1st Qu.:  58.0
##  Median :  0.03000   Median :  0.0800   Median : -57.00   Median : 201.0
##  Mean   :  0.07937   Mean   :  0.1504   Mean   : -61.62   Mean   : 164.5
##  3rd Qu.:  1.64000   3rd Qu.:  0.4900   3rd Qu.:  76.00   3rd Qu.: 312.0
##  Max.   :311.00000   Max.   :231.0000   Max.   : 477.00   Max.   : 923.0
##  accel_forearm_z   magnet_forearm_x  magnet_forearm_y magnet_forearm_z
##  Min.   :-410.00   Min.   :-1280.0   Min.   :-896.0   Min.   :-973.0
##  1st Qu.:-182.00   1st Qu.: -617.0   1st Qu.:   6.0   1st Qu.: 194.0
##  Median : -40.00   Median : -379.0   Median : 592.0   Median : 512.0
##  Mean   : -55.71   Mean   : -312.5   Mean   : 380.2   Mean   : 395.5
##  3rd Qu.:  26.00   3rd Qu.:  -76.0   3rd Qu.: 737.0   3rd Qu.: 653.0
##  Max.   : 291.00   Max.   :  672.0   Max.   :1460.0   Max.   :1090.0
##  classe
##  A:4464
##  B:3038
##  C:2738
##  D:2573
##  E:2886
##
```

### PRINCIPAL COMPONENT ANALYSIS

```
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

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

```
##                             PC1          PC2           PC3           PC4
## roll_belt            -0.298394172  0.150581367 -0.0752769700  0.0262576230
## pitch_belt           -0.044381601 -0.289957345 -0.0694535420  0.0353500752
## yaw_belt             -0.183435912  0.266218107 -0.0229733584  0.0006484367
## total_accel_belt     -0.296359136  0.130455662 -0.0958722071  0.0293266617
## gyros_belt_x          0.107221733  0.184708159  0.1959006794 -0.0403907657
## gyros_belt_y         -0.088588705  0.216372116  0.0838646612 -0.0306465309
## gyros_belt_z          0.181054498  0.035316368  0.1071628786 -0.0399208154
## accel_belt_x          0.029616431  0.293587584  0.0862430827 -0.0377512582
## accel_belt_y         -0.313521407  0.059396743 -0.1034539668  0.0372106951
## accel_belt_z          0.308847817 -0.127028000  0.0711153517 -0.0266439219
## magnet_belt_x         0.003815843  0.290541665  0.0425382601 -0.0240722752
## magnet_belt_y         0.122725482  0.078234382 -0.0734691408  0.0121090330
## magnet_belt_z         0.069167351  0.114652630 -0.0597265712  0.0110568015
## roll_arm              0.049539843 -0.183842011  0.0593849753 -0.0312898482
## pitch_arm             0.042021516  0.065822215 -0.2285556450  0.0670412498
## yaw_arm               0.040514234 -0.123185596  0.0008067361 -0.0128554893
## total_accel_arm       0.108685453 -0.044333272  0.0580772919  0.0008534432
## gyros_arm_x          -0.009165269  0.051106368 -0.0029922874 -0.0023315008
## gyros_arm_y           0.071480234 -0.084088564 -0.0024454385  0.0015072450
## gyros_arm_z          -0.143862005  0.195223170  0.0714638006 -0.0106873441
## accel_arm_x          -0.168052370 -0.096406892  0.1710020192 -0.0559106893
## accel_arm_y           0.259378746 -0.143700667 -0.1321366459  0.0217190767
## accel_arm_z          -0.127433747  0.002900311 -0.2745387582  0.0640796727
## magnet_arm_x         -0.090360971 -0.003902578  0.2668027167 -0.0797454221
## magnet_arm_y          0.066093107  0.020978318 -0.3690785271  0.0937423416
## magnet_arm_z          0.033371120  0.023231875 -0.3066167000  0.0809321827
## roll_dumbbell         0.095788280  0.122655897  0.0584869390 -0.0270383935
## pitch_dumbbell       -0.118361492 -0.141243972  0.0958413830 -0.0382509593
## yaw_dumbbell         -0.141539871 -0.257708532  0.0070500882  0.0115168033
## total_accel_dumbbell  0.177218369  0.135917715 -0.1216966526  0.0395257061
## gyros_dumbbell_x     -0.006136316 -0.009637838 -0.1295715209 -0.4445869878
## gyros_dumbbell_y      0.003418831  0.038776671  0.0874717610  0.3600529676
## gyros_dumbbell_z      0.002542276  0.005008988  0.1134520653  0.4461786352
## accel_dumbbell_x     -0.179272770 -0.126698577  0.1335126996 -0.0538127193
## accel_dumbbell_y      0.193496098  0.168268984 -0.0035271178 -0.0038039915
## accel_dumbbell_z     -0.170097838 -0.236443578  0.0708285626  0.0062374829
## magnet_dumbbell_x    -0.182162378 -0.182508160 -0.1433149670  0.0348506636
## magnet_dumbbell_y     0.157371807  0.160901368  0.2046778408 -0.0452479743
## magnet_dumbbell_z     0.169325025 -0.031752412  0.1840022551 -0.0671852407
## roll_forearm          0.061739550 -0.050542923 -0.1513865100  0.0260621539
## pitch_forearm        -0.152411037 -0.092591612  0.1017830180 -0.0224469691
## yaw_forearm           0.110268864 -0.045900120 -0.1306972219  0.0256234870
## total_accel_forearm   0.006306944  0.095860245 -0.0005564480  0.0202806486
## gyros_forearm_x      -0.057563782  0.196516165 -0.1026694765 -0.1771142928
## gyros_forearm_y       0.001082651  0.020558630  0.1020071041  0.4099281486
## gyros_forearm_z       0.006394048  0.023781999  0.1155330724  0.4474646223
## accel_forearm_x       0.185218779 -0.102584558 -0.1258586785  0.0108232911
## accel_forearm_y       0.041112322  0.088899882 -0.1191758545  0.0338980400
```

```
## accel_forearm_z      -0.028672654  0.043457435  0.2098018819 -0.0621088166
## magnet_forearm_x      0.105352110 -0.017565068  0.0080661019 -0.0096689156
## magnet_forearm_y      0.026269946  0.050221741 -0.1422118011  0.0455956638
## magnet_forearm_z     -0.031356794  0.111658743 -0.1955739496  0.0577768652
##                               PC5          PC6           PC7
## roll_belt             0.0104933170 -0.015688478  0.0396640175
## pitch_belt           -0.0992313074  0.174922273 -0.1223161997
## yaw_belt              0.0518216038 -0.115623266  0.0958785524
## total_accel_belt     -0.0119743145 -0.014908668  0.0409849713
## gyros_belt_x          0.1029485480  0.167728724 -0.0799205177
## gyros_belt_y          0.0634822087  0.147515491 -0.0811132681
## gyros_belt_z          0.0487846545  0.111641150 -0.1558568396
## accel_belt_x          0.1225188909 -0.162584781  0.1000883094
## accel_belt_y         -0.0219106343  0.034677619  0.0077729003
## accel_belt_z         -0.0274804736  0.018408399 -0.0337499649
## magnet_belt_x         0.1159176619 -0.185413297  0.1081904262
## magnet_belt_y        -0.2677723815  0.160369575 -0.0095285635
## magnet_belt_z        -0.2406096375  0.181438104 -0.0462912038
## roll_arm              0.0833065901 -0.222119115  0.0188518541
## pitch_arm             0.1996477011  0.038340035  0.0531191027
## yaw_arm               0.1073540377 -0.141756133  0.0158225762
## total_accel_arm      -0.0710463859 -0.016639808 -0.0561466751
## gyros_arm_x           0.0124290079 -0.050069527 -0.5146284629
## gyros_arm_y           0.0083214639  0.060209319  0.4886497222
## gyros_arm_z           0.0166230716  0.080868986 -0.2239275323
## accel_arm_x          -0.2695103081 -0.211085095  0.0626405347
## accel_arm_y           0.1201575285 -0.006303541  0.0297258028
## accel_arm_z           0.1727486469  0.053556268  0.1100555355
## magnet_arm_x         -0.2446393464 -0.101610108  0.0670731465
## magnet_arm_y          0.1992899544  0.105583118 -0.0006948747
## magnet_arm_z          0.2757990634  0.153233391  0.0094660475
## roll_dumbbell        -0.0846620216 -0.063117664  0.1523878072
## pitch_dumbbell        0.0754070961 -0.083933552  0.0666195465
## yaw_dumbbell          0.0205653591  0.017802578 -0.0669118924
## total_accel_dumbbell -0.1586805001 -0.118291001  0.1459950374
## gyros_dumbbell_x     -0.0280288404  0.010665984  0.0055960339
## gyros_dumbbell_y     -0.0234636269  0.017423406  0.0054552729
## gyros_dumbbell_z      0.0185002349 -0.023038669  0.0132212119
## accel_dumbbell_x      0.1627036989 -0.052116924 -0.0005617295
## accel_dumbbell_y     -0.1408561390 -0.088682276  0.1542281408
## accel_dumbbell_z      0.1449167293 -0.021179334 -0.0761800976
## magnet_dumbbell_x    -0.0616302813 -0.202412971  0.1196774328
## magnet_dumbbell_y     0.0507385579  0.208672701 -0.0704421780
## magnet_dumbbell_z     0.2450512759 -0.227525298  0.0536016165
## roll_forearm         -0.1873804553 -0.141594209 -0.0515026333
## pitch_forearm        -0.0726027399  0.098302496  0.0777376148
## yaw_forearm          -0.0575764140 -0.282380054 -0.1376701335
## total_accel_forearm   0.0211428100 -0.203120801 -0.0121461492
## gyros_forearm_x       0.0313042825 -0.136715876  0.0745358822
## gyros_forearm_y      -0.0149229961 -0.026122256  0.0289034302
## gyros_forearm_z       0.0167524850 -0.068522721  0.0266561290
## accel_forearm_x      -0.0173221507 -0.177922928  0.0183285500
## accel_forearm_y       0.0007069872 -0.401144317 -0.1865982752
## accel_forearm_z       0.3356149191 -0.077902627 -0.0743227003
```

```
## magnet_forearm_x      0.1052638150  0.011038247  0.1537794611
## magnet_forearm_y     -0.0247038730 -0.220561321 -0.3501602131
## magnet_forearm_z     -0.3322382870  0.012643449 -0.0324573456
##                               PC8           PC9          PC10
## roll_belt           -8.621424e-02  0.0140879338 -0.0059565669
## pitch_belt          -3.552830e-02 -0.0193638307 -0.0401046542
## yaw_belt            -4.160774e-02  0.0201396853  0.0160933405
## total_accel_belt    -9.672626e-02  0.0197648991  0.0024915535
## gyros_belt_x         5.241066e-02 -0.0542898676 -0.1261895476
## gyros_belt_y        -3.180984e-02 -0.0726911117 -0.0545933473
## gyros_belt_z         2.102138e-02 -0.1465588311  0.0510668937
## accel_belt_x         1.759457e-02 -0.0002479477  0.0322540971
## accel_belt_y        -8.851544e-02  0.0234522080 -0.0147340307
## accel_belt_z         9.051263e-02 -0.0051242927  0.0133838577
## magnet_belt_x       -2.333148e-02  0.0116038498  0.0655119843
## magnet_belt_y        1.439292e-01  0.0989259665 -0.0228247503
## magnet_belt_z        1.967719e-01  0.0927469592 -0.1217861581
## roll_arm             1.017960e-01 -0.0238217985  0.1507553609
## pitch_arm            3.215260e-02  0.0463293060 -0.0030956419
## yaw_arm              4.604414e-02 -0.0584710476  0.2291781361
## total_accel_arm     -3.342600e-01  0.1566451972 -0.2540288048
## gyros_arm_x          6.651636e-02  0.2965016827  0.3158665756
## gyros_arm_y         -5.410700e-02 -0.3027335183 -0.3060030193
## gyros_arm_z         -3.770689e-02  0.1348454179  0.0201089584
## accel_arm_x          1.101472e-02 -0.0314542577  0.1818646849
## accel_arm_y          1.337598e-01 -0.0022568425  0.1339150467
## accel_arm_z          2.651245e-01 -0.0654633547  0.1761778827
## magnet_arm_x         1.361923e-01 -0.1063659055  0.2193898205
## magnet_arm_y         3.766460e-02  0.1064754212  0.0132713651
## magnet_arm_z         2.019550e-01 -0.0245352149  0.0563161053
## roll_dumbbell        2.919248e-01  0.3500036113 -0.1583684425
## pitch_dumbbell       2.690848e-01  0.3586407670 -0.2754673942
## yaw_dumbbell         5.888716e-02  0.0870419757 -0.1541020090
## total_accel_dumbbell -2.591943e-02  0.0918297443  0.1717986400
## gyros_dumbbell_x     -2.850751e-02 -0.0074561654 -0.0046595343
## gyros_dumbbell_y     -4.660064e-02 -0.0072416226 -0.0271468737
## gyros_dumbbell_z      2.609401e-02  0.0103292251  0.0219560053
## accel_dumbbell_x      1.816772e-01  0.2229529687 -0.2396874214
## accel_dumbbell_y      1.700836e-01  0.2264107725 -0.0054974271
## accel_dumbbell_z      5.323511e-02  0.0558791361 -0.1358141684
## magnet_dumbbell_x     2.891018e-02  0.1895859335  0.0155879713
## magnet_dumbbell_y     1.238725e-01  0.0380528607 -0.1509640989
## magnet_dumbbell_z     1.607152e-02  0.0309764634  0.0702634283
## roll_forearm         -2.397230e-03 -0.0230516345 -0.0007091415
## pitch_forearm         2.695183e-01 -0.1284715919  0.1488485123
## yaw_forearm           6.367105e-02 -0.1392679551 -0.0626896729
## total_accel_forearm   2.521254e-01 -0.0954756418 -0.1246197696
## gyros_forearm_x       3.172940e-02  0.0160256807 -0.0160500578
## gyros_forearm_y      -6.794084e-05  0.0152173905  0.0110289451
## gyros_forearm_z       1.822660e-02  0.0130249779  0.0252404599
## accel_forearm_x      -2.851495e-01  0.1919486634 -0.0454814018
## accel_forearm_y       4.744202e-02 -0.1513195290 -0.2420712283
## accel_forearm_z      -5.314908e-02 -0.0551519545 -0.0227948409
## magnet_forearm_x     -3.759520e-01  0.3479935615  0.0734699725
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## magnet_forearm_y      1.311526e-02 -0.2298319838 -0.3333378276
## magnet_forearm_z      2.194182e-02  0.0130119266 -0.0931372459
##                              PC11         PC12         PC13          PC14
## roll_belt             0.0001242319 -0.028369390  0.029756728 -0.0203183591
## pitch_belt           -0.0216987171 -0.160541747 -0.047704073  0.0149465826
## yaw_belt              0.0145583608  0.129110364  0.051062681  0.0089376810
## total_accel_belt     -0.0034098258 -0.059157221  0.034124549 -0.0072949182
## gyros_belt_x          0.0698569077 -0.061192240  0.088479504  0.1960603169
## gyros_belt_y          0.1874989056  0.030179706  0.031857673 -0.4371957277
## gyros_belt_z          0.1759120423  0.022617490 -0.045676382 -0.5990930947
## accel_belt_x          0.0253541111  0.099424526  0.066048356 -0.0275969528
## accel_belt_y         -0.0109759124 -0.034602822  0.017303122  0.0040742213
## accel_belt_z         -0.0030167118  0.057692837 -0.030145687  0.0318764472
## magnet_belt_x        -0.0375868193  0.058099359  0.094120973  0.0537739151
## magnet_belt_y         0.0467516631  0.380279279  0.017185924  0.1312763365
## magnet_belt_z         0.0458403090  0.457504794  0.060324077  0.1942829333
## roll_arm             -0.0242391194  0.311344631  0.224419823 -0.0584752906
## pitch_arm            -0.2793470137  0.071556815  0.059595856 -0.1392444755
## yaw_arm               0.0885692171  0.120164498  0.451204612  0.1507282330
## total_accel_arm      -0.4325555707  0.093400454  0.211161901 -0.1309035685
## gyros_arm_x          -0.0712730977 -0.016885620 -0.040343346 -0.0227830129
## gyros_arm_y           0.0436083565  0.009703911  0.040768864 -0.0091133291
## gyros_arm_z          -0.0362152372 -0.013223375  0.075368872  0.0823427981
## accel_arm_x           0.0369771883  0.002706329 -0.133550711  0.0131009331
## accel_arm_y           0.0170327785 -0.063298022 -0.043168610  0.0176732223
## accel_arm_z           0.2117171552 -0.034770626 -0.124310979  0.0386902567
## magnet_arm_x          0.2064620238 -0.047305992 -0.171782424  0.0625533724
## magnet_arm_y         -0.0599123976 -0.019931632  0.065588734 -0.0094966686
## magnet_arm_z          0.1331785683 -0.031498225 -0.046335952  0.0384917532
## roll_dumbbell        -0.0065151972 -0.256031569 -0.033359201 -0.0100959485
## pitch_dumbbell        0.0754809213 -0.039430886  0.053956895 -0.1008895762
## yaw_dumbbell          0.0524608096  0.040529786 -0.051915693  0.0257393323
## total_accel_dumbbell -0.1577140981 -0.222585653 -0.030580790 -0.0048674233
## gyros_dumbbell_x     -0.0410387955 -0.044475542  0.014834448  0.0005772211
## gyros_dumbbell_y      0.0078899848 -0.152594850 -0.001378195  0.0964347822
## gyros_dumbbell_z      0.0404649469  0.063595557 -0.007955617 -0.0317910377
## accel_dumbbell_x      0.1246406540  0.116520836  0.129079440 -0.1020977234
## accel_dumbbell_y     -0.0506177654 -0.248112252  0.073538432 -0.0194789509
## accel_dumbbell_z      0.0455498294  0.066557332 -0.051172336  0.0221462394
## magnet_dumbbell_x    -0.0981912824 -0.082363225 -0.034197026 -0.0927524456
## magnet_dumbbell_y     0.1005496244 -0.172240435  0.070289190  0.0373859333
## magnet_dumbbell_z    -0.0415841872 -0.071981925 -0.006087497  0.0570806416
## roll_forearm          0.1979115758 -0.134978019  0.329370696 -0.2780713113
## pitch_forearm        -0.1071212713 -0.112650303  0.385018834 -0.0828137830
## yaw_forearm          -0.0581264622  0.067451276  0.059770219 -0.1152513953
## total_accel_forearm  -0.2609907590  0.191284391 -0.483395880 -0.2153660261
## gyros_forearm_x       0.0621037215  0.158419480 -0.002493601 -0.0050416895
## gyros_forearm_y      -0.0073500600  0.042894275  0.042392707 -0.0156183610
## gyros_forearm_z       0.0157071967  0.065100421  0.017439347 -0.0540474554
## accel_forearm_x       0.3202279919  0.025052575 -0.087347156  0.0331653152
## accel_forearm_y       0.1689569832  0.006396214  0.038514280  0.0679522898
## accel_forearm_z       0.0227798913 -0.130437521  0.041233632  0.1245865101
## magnet_forearm_x      0.3733660266  0.131548335 -0.111880693 -0.0322776523
## magnet_forearm_y      0.1017016265 -0.167097573 -0.004876807  0.2228741383
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## magnet_forearm_z      0.2085620579 -0.082584243  0.152959433 -0.0934878553
##                              PC15         PC16          PC17         PC18
## roll_belt             0.056946696 -0.068050682  0.0229535921 -0.014198519
## pitch_belt            0.069381484 -0.144766041  0.0212834479  0.103869762
## yaw_belt              0.027935974  0.027372383 -0.0146764258 -0.065023990
## total_accel_belt      0.078582323 -0.091965770  0.0184104614  0.004315004
## gyros_belt_x         -0.016725445  0.062456765  0.2058859918  0.075135342
## gyros_belt_y          0.127917159 -0.266186920 -0.2014333761  0.070309915
## gyros_belt_z          0.015699012 -0.181667530 -0.2209397318 -0.026199354
## accel_belt_x         -0.079192039  0.114672048 -0.0074456816 -0.117730952
## accel_belt_y          0.105972035 -0.102442710 -0.0020908920  0.037719379
## accel_belt_z         -0.009081135  0.056847714 -0.0310082062  0.022199591
## magnet_belt_x         0.022861997  0.030949103 -0.0257723175 -0.017644943
## magnet_belt_y         0.336667609 -0.067884365 -0.1415143945  0.067209751
## magnet_belt_z         0.187499870 -0.038426767 -0.0651035418  0.060067851
## roll_arm             -0.089901244  0.095650696 -0.1153769604  0.109227106
## pitch_arm             0.190986515  0.276255605 -0.1721690723  0.189229638
## yaw_arm              -0.103549070 -0.602824978  0.1783623787 -0.182192727
## total_accel_arm      -0.058862919 -0.053119072 -0.1207864477 -0.037180656
## gyros_arm_x          -0.084619949  0.056362415 -0.0294599765 -0.013399921
## gyros_arm_y           0.049240312 -0.071468738  0.0004983269  0.030900421
## gyros_arm_z           0.081053696 -0.041256661  0.1416600802  0.082181198
## accel_arm_x           0.092648001 -0.018711792 -0.0941157561  0.043039429
## accel_arm_y          -0.033130546 -0.009526297 -0.0416095977 -0.022759958
## accel_arm_z           0.052576088  0.019181100 -0.0479694879 -0.009159211
## magnet_arm_x          0.076639427  0.039115166 -0.0435525648  0.035218128
## magnet_arm_y         -0.028786950 -0.107042528  0.0168772736 -0.063567528
## magnet_arm_z          0.014944341  0.033991028 -0.0028002666 -0.013312398
## roll_dumbbell        -0.064849788 -0.138950240 -0.0811067891  0.019143707
## pitch_dumbbell       -0.047602109 -0.005826187  0.0116077525 -0.058383404
## yaw_dumbbell          0.097117325 -0.060394728 -0.0573723759  0.155560068
## total_accel_dumbbell  0.194760612 -0.160878151 -0.0896659656  0.063091518
## gyros_dumbbell_x      0.090683204  0.037144342  0.0112875484 -0.168535885
## gyros_dumbbell_y     -0.227161815 -0.038747058 -0.0028058645  0.381635272
## gyros_dumbbell_z     -0.063763289 -0.038331809 -0.0203670752  0.140926871
## accel_dumbbell_x     -0.064300248  0.086801572  0.0752403138 -0.109115046
## accel_dumbbell_y      0.064034176 -0.155432798 -0.0553333339  0.025702246
## accel_dumbbell_z      0.127273360 -0.049834844 -0.0136727539  0.117913260
## magnet_dumbbell_x     0.138236583 -0.097300739 -0.0951339060  0.015363734
## magnet_dumbbell_y     0.013319850 -0.021591219  0.1372277232  0.023321778
## magnet_dumbbell_z     0.297959310  0.055220489 -0.0633213260  0.083557880
## roll_forearm          0.246429216  0.337966291  0.4556351961  0.183760582
## pitch_forearm        -0.118442487  0.209461110 -0.2484635594  0.013373560
## yaw_forearm           0.166057998 -0.184599695  0.3262194340  0.221499806
## total_accel_forearm  -0.074018419 -0.087043472  0.3548697479 -0.131320946
## gyros_forearm_x      -0.319451806 -0.067242150 -0.0374987427  0.518922207
## gyros_forearm_y       0.192716972  0.083846009  0.0314699376 -0.415185385
## gyros_forearm_z       0.034734481  0.006290531 -0.0256393079 -0.021600887
## accel_forearm_x      -0.073627055  0.040839490 -0.1382524559 -0.037615231
## accel_forearm_y      -0.069037884  0.115881722 -0.2393027645 -0.094074784
## accel_forearm_z       0.432328689 -0.028766681 -0.0623729695  0.089302139
## magnet_forearm_x      0.028004420  0.029520347  0.0951774227  0.028966264
## magnet_forearm_y      0.035078029 -0.089298355 -0.2474230872 -0.048407630
## magnet_forearm_z     -0.098372823  0.102036909  0.0260511658 -0.165105795
```

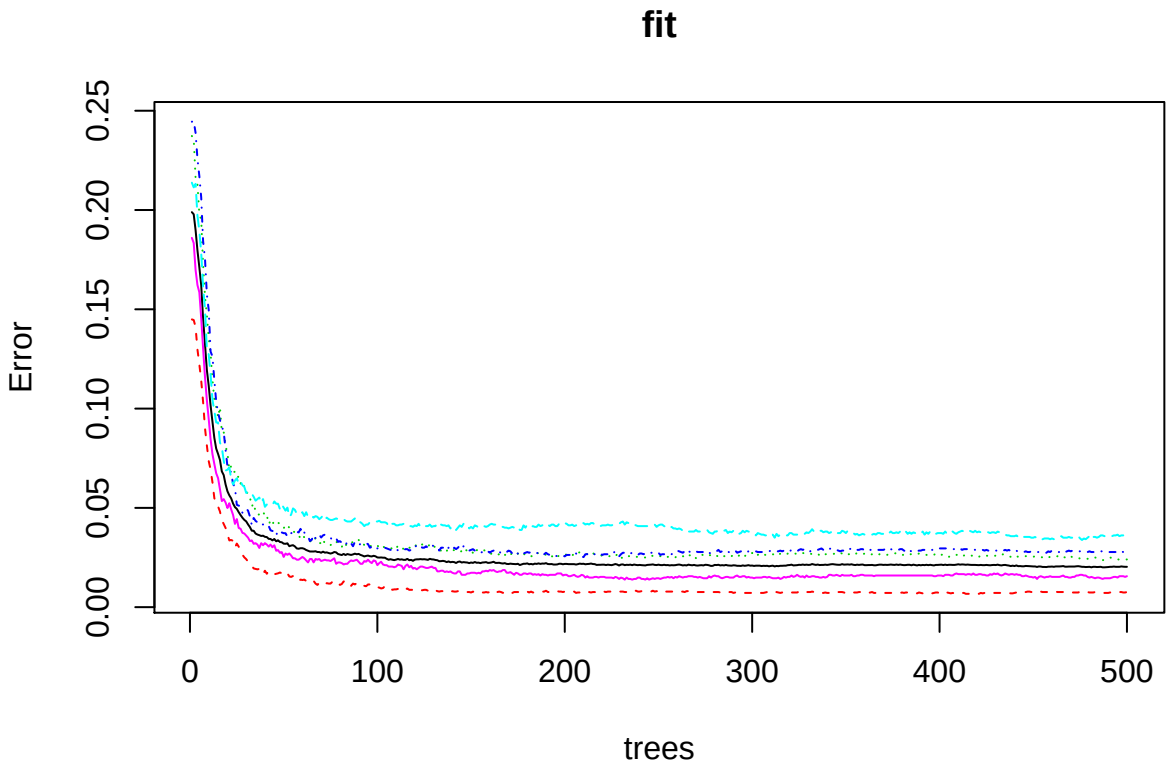
```
##                             PC19         PC20          PC21         PC22
## roll_belt            -0.034288456  0.001032192  0.0358218786  0.006320416
## pitch_belt           -0.011855794 -0.042551428  0.0263574927 -0.025707562
## yaw_belt             -0.028037078  0.030414315  0.0034209380  0.020620389
## total_accel_belt     -0.041922881  0.001767847  0.0382707632  0.013651037
## gyros_belt_x         -0.056684003 -0.061279883  0.0030959873  0.063291410
## gyros_belt_y          0.008976831 -0.040499724  0.0821316814 -0.050036999
## gyros_belt_z         -0.039092760  0.010170527 -0.0337190847  0.093483231
## accel_belt_x          0.023575234  0.065680027 -0.0234621314  0.063956661
## accel_belt_y         -0.025264969 -0.014247583  0.0433371564 -0.009385027
## accel_belt_z          0.038822294  0.017405671 -0.0247255609 -0.029603208
## magnet_belt_x        -0.037072339  0.096235539 -0.0397261317  0.155461375
## magnet_belt_y         0.070061567  0.092695313  0.1180410089 -0.207294015
## magnet_belt_z        -0.009970700  0.018597557  0.0009774332  0.011858477
## roll_arm             -0.215497950 -0.240600653  0.3866744948  0.450393615
## pitch_arm            -0.141207973 -0.575258809 -0.3785782408 -0.212942322
## yaw_arm               0.161723840 -0.313680781 -0.1463149377 -0.201819570
## total_accel_arm       0.101937421  0.099646801  0.0740727170 -0.134409202
## gyros_arm_x           0.036454829  0.049511723 -0.0549737324 -0.049651166
## gyros_arm_y          -0.008927533 -0.026801571  0.0221974723  0.013006357
## gyros_arm_z          -0.093341618 -0.165793172  0.2092036720  0.094698114
## accel_arm_x          -0.011676754 -0.056958967 -0.1245941146 -0.097072093
## accel_arm_y           0.064396702  0.117711755  0.0833027365 -0.029973459
## accel_arm_z          -0.037331734  0.038830859  0.0744915300 -0.045321319
## magnet_arm_x         -0.062824348 -0.111472134 -0.0832727361 -0.130473678
## magnet_arm_y          0.048232272  0.157461083  0.1021050275 -0.005045980
## magnet_arm_z         -0.021965906  0.040712293  0.0365219829  0.010889818
## roll_dumbbell        -0.081725796 -0.142550968 -0.2765814017  0.185260701
## pitch_dumbbell       -0.052058652  0.085874246 -0.0522022577 -0.114027393
## yaw_dumbbell          0.150008823 -0.063491064  0.0038509815  0.341101574
## total_accel_dumbbell  0.092936894 -0.039928188  0.2036545543  0.153963832
## gyros_dumbbell_x     -0.117024304 -0.064596154  0.0776319700  0.012617903
## gyros_dumbbell_y     -0.221076642 -0.163719614  0.3615192240 -0.218069825
## gyros_dumbbell_z      0.156525543  0.084614291 -0.1250605320  0.006896093
## accel_dumbbell_x     -0.064356139  0.108339721  0.0773593623 -0.173067228
## accel_dumbbell_y     -0.028529779  0.004188528  0.1121157948  0.059320961
## accel_dumbbell_z      0.107208132 -0.143808162 -0.0075232406  0.216393274
## magnet_dumbbell_x     0.024412749  0.071007941  0.1102221786 -0.076159333
## magnet_dumbbell_y    -0.032826622 -0.129447812  0.0850468557 -0.053180930
## magnet_dumbbell_z     0.131530085  0.091060139  0.1579538368 -0.110571828
## roll_forearm          0.336850672 -0.038692744 -0.0160453283  0.010763443
## pitch_forearm        -0.109656269  0.125755064  0.1628557310 -0.300923220
## yaw_forearm          -0.624839070  0.309190901 -0.1773763610 -0.020758900
## total_accel_forearm   0.155745981 -0.231962654  0.2953543171 -0.218547504
## gyros_forearm_x       0.269042105  0.168526492 -0.1235191797 -0.015032254
## gyros_forearm_y      -0.117728462  0.006485151 -0.0387939974  0.120861132
## gyros_forearm_z       0.102601892  0.082767776 -0.1158642741  0.046486599
## accel_forearm_x      -0.092266097 -0.086004679  0.0578978179 -0.117605868
## accel_forearm_y       0.073817274 -0.073757733  0.0380817625 -0.094216906
## accel_forearm_z       0.111631664  0.079228649  0.0936714589 -0.129763321
## magnet_forearm_x     -0.162098833 -0.086321656  0.0650790821 -0.170892121
## magnet_forearm_y     -0.021551321 -0.057399410 -0.0198159332 -0.025581599
## magnet_forearm_z      0.060210115 -0.132694421  0.1627752947  0.037518674
##                             PC23         PC24         PC25
```

```
## roll_belt            -0.053516492 -0.073670410  0.037827335
## pitch_belt            0.092251988 -0.130406468  0.214171247
## yaw_belt             -0.093085159  0.041942851 -0.075212523
## total_accel_belt     -0.039153960 -0.090085438  0.106913353
## gyros_belt_x         -0.266080436 -0.078075317  0.578099861
## gyros_belt_y          0.030419698 -0.136558500 -0.179840577
## gyros_belt_z         -0.116204943  0.242280536  0.216052228
## accel_belt_x         -0.088433795  0.111929543 -0.164612297
## accel_belt_y         -0.032268016 -0.125905672  0.109438019
## accel_belt_z          0.043280330  0.065320157 -0.037837814
## magnet_belt_x        -0.157937186  0.193356135  0.139620359
## magnet_belt_y         0.007485404 -0.131879662 -0.213025699
## magnet_belt_z        -0.109566709  0.158765509  0.178816433
## roll_arm              0.115200673 -0.351132310  0.056200483
## pitch_arm            -0.020478458 -0.012242248  0.074496564
## yaw_arm              -0.060576127  0.063399401 -0.016967244
## total_accel_arm      -0.092675565  0.159490788  0.099268091
## gyros_arm_x          -0.155698928 -0.117956637 -0.027377192
## gyros_arm_y           0.104749385  0.057451490  0.003205567
## gyros_arm_z           0.641427714  0.511096584  0.026746303
## accel_arm_x          -0.033855927  0.081474701  0.087047968
## accel_arm_y           0.004588119  0.110396501  0.036372887
## accel_arm_z          -0.047784735  0.142076500  0.080486375
## magnet_arm_x         -0.032321333  0.114058698  0.103957288
## magnet_arm_y         -0.019796103  0.004019902  0.027854111
## magnet_arm_z          0.026545770  0.083857435 -0.006295815
## roll_dumbbell         0.086389233 -0.062065839 -0.211374780
## pitch_dumbbell        0.036215847 -0.002598457  0.111440038
## yaw_dumbbell         -0.240341513  0.252360294 -0.056447866
## total_accel_dumbbell -0.051755986 -0.015981737  0.187335489
## gyros_dumbbell_x     -0.125715490  0.063167778 -0.043232093
## gyros_dumbbell_y     -0.392336443  0.217155652 -0.276855144
## gyros_dumbbell_z      0.178995443 -0.088033532  0.086030497
## accel_dumbbell_x     -0.052075644  0.023995490  0.033566491
## accel_dumbbell_y      0.005058233 -0.019916644  0.062297881
## accel_dumbbell_z     -0.162600242  0.088880240 -0.100576378
## magnet_dumbbell_x    -0.033053042  0.043603536  0.168238228
## magnet_dumbbell_y     0.005451929 -0.176636984 -0.027736375
## magnet_dumbbell_z    -0.010795942  0.073183973 -0.025836410
## roll_forearm         -0.034298683  0.074418859 -0.046535414
## pitch_forearm         0.113447576  0.024676327  0.132371983
## yaw_forearm           0.001061528 -0.015058288 -0.057775624
## total_accel_forearm   0.030473138 -0.069929665  0.101234458
## gyros_forearm_x       0.077421914 -0.089974981  0.138339609
## gyros_forearm_y      -0.086924938  0.022824334  0.047318011
## gyros_forearm_z       0.125484183 -0.074864023  0.086146600
## accel_forearm_x       0.076583907  0.037795454  0.126095691
## accel_forearm_y       0.044185945  0.069178410 -0.007428980
## accel_forearm_z       0.026497197 -0.221870634 -0.083435220
## magnet_forearm_x      0.050891020 -0.074253237  0.108501681
## magnet_forearm_y      0.069191141 -0.055052699  0.109132552
## magnet_forearm_z     -0.075506657 -0.133099657 -0.053633034
```

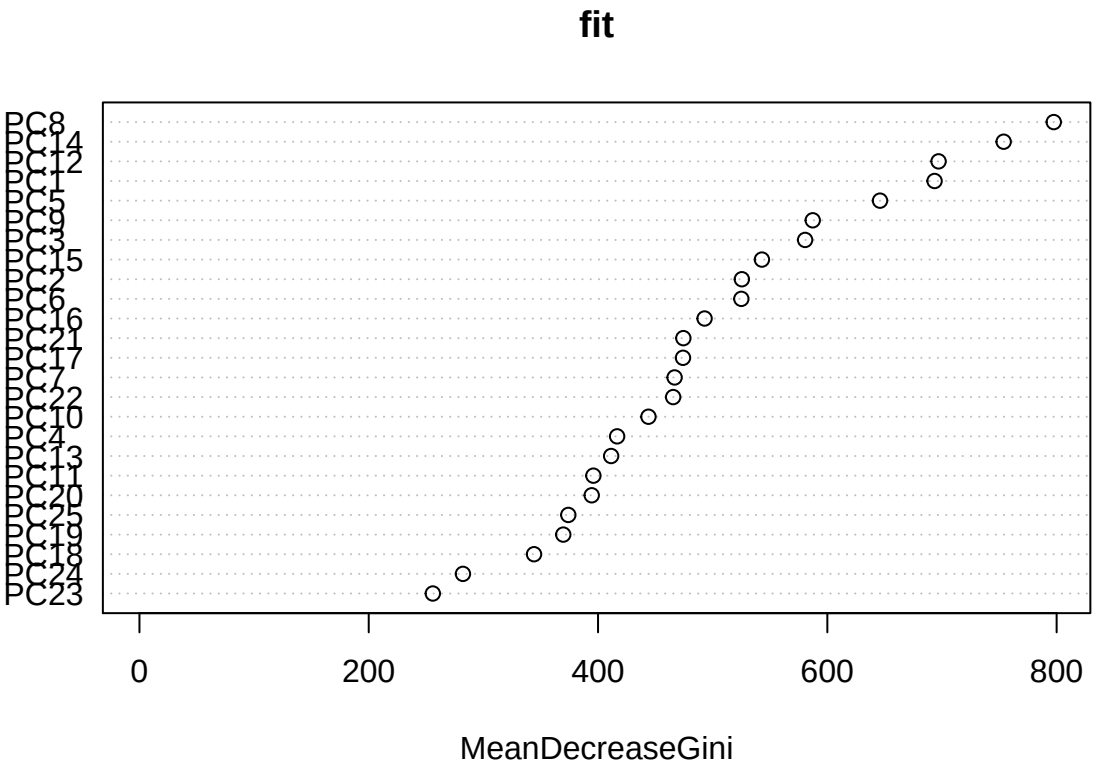
```
training_preprocess <- predict(pre_process, training_columns[,1:52])
```

### RANDOM FOREST

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




```
varImpPlot(fit)
```




## MODEL VALIDATION

### 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 1110    1    5    0    0
##          B   12  738    7    0    2
##          C    1    5  671    7    0
##          D    2    0   21  620    0
##          E    0    2    4    2  713
##
## Overall Statistics
##
##                Accuracy : 0.9819
##                  95% CI : (0.9772, 0.9858)
##     No Information Rate : 0.2868
##     P-Value [Acc > NIR] : < 2.2e-16
```

```
##
##                   Kappa : 0.9771
##  Mcnemar's Test P-Value : NA
##
## Statistics by Class:
##
##                      Class: A Class: B Class: C Class: D Class: E
## Sensitivity            0.9867   0.9893   0.9477   0.9857   0.9972
## Specificity            0.9979   0.9934   0.9960   0.9930   0.9975
## Pos Pred Value         0.9946   0.9723   0.9810   0.9642   0.9889
## Neg Pred Value         0.9947   0.9975   0.9886   0.9973   0.9994
## Prevalence             0.2868   0.1902   0.1805   0.1603   0.1823
## Detection Rate         0.2829   0.1881   0.1710   0.1580   0.1817
## Detection Prevalence   0.2845   0.1935   0.1744   0.1639   0.1838
## Balanced Accuracy      0.9923   0.9913   0.9718   0.9894   0.9974
```

```
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 A A A E D B A A A C B A E E A B B B
## Levels: A B C D E
```