

CourseProject:Prediction Assignment

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Prediction Assignment

```
# required machine learning packages
#install.packages("caret")
#install.packages("randomForest")
#install.packages("rpart")
#install.packages("rpart.plot")
#install.packages("ROCR")

# Other required packages
#install.packages("tidyverse")

library(caret)

## Loading required package: lattice
## Loading required package: ggplot2
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:ggplot2':
## 
##     margin
library(rpart)
library(rpart.plot)
library(ROCR)

## Loading required package: gplots
##
## Attaching package: 'gplots'
## The following object is masked from 'package:stats':
## 
##     lowess
library(tidyverse)

## -- Attaching packages -----
## v tibble  1.4.2      v purrr   0.2.4
## v tidyr   0.8.0      v dplyr   0.7.4
## v readr   1.1.1      v stringr 1.3.0
## v tibble  1.4.2      vforcats 0.3.0
```

```

## -- Conflicts ----- tidyverse
## x dplyr::combine()     masks randomForest::combine()
## x dplyr::filter()      masks stats::filter()
## x dplyr::lag()         masks stats::lag()
## x purrr::lift()        masks caret::lift()
## x randomForest::margin() masks ggplot2::margin()

# setting seed
set.seed(1234)

```

1. Load training and tests datasets from given urls.

```

trainingdata <- read.csv("https://d396qusza40orc.cloudfront.net/predmachlearn/pml-training.csv")
testdata <- read.csv("https://d396qusza40orc.cloudfront.net/predmachlearn/pml-testing.csv")

```

saved to local working directory

```

write.csv(trainingdata, "trainingdata.csv")
write.csv(testdata, "testdata.csv")

```

Structure of data

```
str(trainingdata)
```

```

## 'data.frame': 19622 obs. of 160 variables:
## $ X                  : int 1 2 3 4 5 6 7 8 9 10 ...
## $ user_name          : Factor w/ 6 levels "adelmo","carlitos",...: 2 2 2 2 2 2 2 2 2 2 ...
## $ raw_timestamp_part_1 : int 1323084231 1323084231 1323084231 1323084232 1323084232 1323084232 ...
## $ raw_timestamp_part_2 : int 788290 808298 820366 120339 196328 304277 368296 440390 484323 484323 ...
## $ cvtd_timestamp      : Factor w/ 20 levels "02/12/2011 13:32",...: 9 9 9 9 9 9 9 9 9 9 ...
## $ new_window          : Factor w/ 2 levels "no","yes": 1 1 1 1 1 1 1 1 1 1 ...
## $ num_window          : int 11 11 11 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 8.05 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 ...
## $ kurtosis_roll_belt : Factor w/ 397 levels "", "-0.016850",...: 1 1 1 1 1 1 1 1 1 1 ...
## $ kurtosis_pitch_belt: Factor w/ 317 levels "", "-0.021887",...: 1 1 1 1 1 1 1 1 1 1 ...
## $ kurtosis_yaw_belt   : Factor w/ 2 levels "", "#DIV/0!": 1 1 1 1 1 1 1 1 1 1 ...
## $ skewness_roll_belt  : Factor w/ 395 levels "", "-0.003095",...: 1 1 1 1 1 1 1 1 1 1 ...
## $ skewness_roll_belt.1: Factor w/ 338 levels "", "-0.005928",...: 1 1 1 1 1 1 1 1 1 1 ...
## $ skewness_yaw_belt   : Factor w/ 2 levels "", "#DIV/0!": 1 1 1 1 1 1 1 1 1 1 ...
## $ max_roll_belt       : num NA NA NA NA NA NA NA NA ...
## $ max_pitch_belt      : int NA NA NA NA NA NA NA NA ...
## $ max_yaw_belt        : Factor w/ 68 levels "", "-0.1", "-0.2", ...: 1 1 1 1 1 1 1 1 1 1 ...
## $ min_roll_belt       : num NA NA NA NA NA NA NA NA ...
## $ min_pitch_belt      : int NA NA NA NA NA NA NA NA ...
## $ min_yaw_belt        : Factor w/ 68 levels "", "-0.1", "-0.2", ...: 1 1 1 1 1 1 1 1 1 1 ...

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## $ amplitude_roll_belt : num NA ...
## $ amplitude_pitch_belt : int NA ...
## $ amplitude_yaw_belt : Factor w/ 4 levels "", "#DIV/0!", "0.00", ... : 1 1 1 1 1 1 1 1 1 1 ...
## $ var_total_accel_belt : num NA ...
## $ avg_roll_belt : num NA ...
## $ stddev_roll_belt : num NA ...
## $ var_roll_belt : num NA ...
## $ avg_pitch_belt : num NA ...
## $ stddev_pitch_belt : num NA ...
## $ var_pitch_belt : num NA ...
## $ avg_yaw_belt : num NA ...
## $ stddev_yaw_belt : num NA ...
## $ var_yaw_belt : num 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 ...
## $ avg_roll_arm : num NA NA NA NA NA NA NA NA NA ...
## $ stddev_roll_arm : num NA NA NA NA NA NA NA NA NA ...
## $ var_roll_arm : num NA NA NA NA NA NA NA NA NA ...
## $ avg_pitch_arm : num NA NA NA NA NA NA NA NA NA ...
## $ stddev_pitch_arm : num NA NA NA NA NA NA NA NA NA ...
## $ var_pitch_arm : num NA NA NA NA NA NA NA NA NA ...
## $ avg_yaw_arm : num NA NA NA NA NA NA NA NA NA ...
## $ stddev_yaw_arm : num NA NA NA NA NA NA NA NA NA ...
## $ var_yaw_arm : num NA NA NA NA NA NA NA NA NA ...
## $ gyros_arm_x : num 0 0.02 0.02 0.02 0 0.02 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 -0.02 -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 -122 -125 -124 -122 -124 -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 : Factor w/ 330 levels "", "-0.02438", ... : 1 1 1 1 1 1 1 1 1 1 ...
## $ kurtosis_pitch_arm : Factor w/ 328 levels "", "-0.00484", ... : 1 1 1 1 1 1 1 1 1 1 ...
## $ kurtosis_yaw_arm : Factor w/ 395 levels "", "-0.01548", ... : 1 1 1 1 1 1 1 1 1 1 ...
## $ skewness_roll_arm : Factor w/ 331 levels "", "-0.00051", ... : 1 1 1 1 1 1 1 1 1 1 ...
## $ skewness_pitch_arm : Factor w/ 328 levels "", "-0.00184", ... : 1 1 1 1 1 1 1 1 1 1 ...
## $ skewness_yaw_arm : Factor w/ 395 levels "", "-0.00311", ... : 1 1 1 1 1 1 1 1 1 1 ...
## $ max_roll_arm : num NA NA NA NA NA NA NA NA ...
## $ max_pitch_arm : num NA NA NA NA NA NA NA NA NA ...
## $ max_yaw_arm : int NA NA NA NA NA NA NA NA ...

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## $ min_roll_arm : num NA ...
## $ min_pitch_arm : num NA ...
## $ min_yaw_arm : int NA ...
## $ amplitude_roll_arm : num NA ...
## $ amplitude_pitch_arm : num NA ...
## $ amplitude_yaw_arm : int 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 : Factor w/ 398 levels "", "-0.0035", "-0.0073", ...: 1 1 1 1 1 1 1 1 1 1 ...
## $ kurtosis_pitch_dumbbell : Factor w/ 401 levels "", "-0.0163", "-0.0233", ...: 1 1 1 1 1 1 1 1 1 1 ...
## $ kurtosis_yaw_dumbbell : Factor w/ 2 levels "", "#DIV/0!": 1 1 1 1 1 1 1 1 ...
## $ skewness_roll_dumbbell : Factor w/ 401 levels "", "-0.0082", "-0.0096", ...: 1 1 1 1 1 1 1 1 1 1 ...
## $ skewness_pitch_dumbbell : Factor w/ 402 levels "", "-0.0053", "-0.0084", ...: 1 1 1 1 1 1 1 1 1 1 ...
## $ skewness_yaw_dumbbell : Factor w/ 2 levels "", "#DIV/0!": 1 1 1 1 1 1 1 1 1 ...
## $ max_roll_dumbbell : num NA NA NA NA NA NA NA NA NA ...
## $ max_pitch_dumbbell : num NA NA NA NA NA NA NA NA NA ...
## $ max_yaw_dumbbell : Factor w/ 73 levels "", "-0.1", "-0.2", ...: 1 1 1 1 1 1 1 1 1 ...
## $ min_roll_dumbbell : num NA NA NA NA NA NA NA NA NA ...
## $ min_pitch_dumbbell : num NA NA NA NA NA NA NA NA NA ...
## $ min_yaw_dumbbell : Factor w/ 73 levels "", "-0.1", "-0.2", ...: 1 1 1 1 1 1 1 1 1 ...
## $ amplitude_roll_dumbbell : num NA NA NA NA NA NA NA NA NA ...
## [list output truncated]

str(testdata)

## 'data.frame': 20 obs. of 160 variables:
## $ X : int 1 2 3 4 5 6 7 8 9 10 ...
## $ user_name : Factor w/ 6 levels "adelmo", "carlitos", ...: 6 5 5 1 4 5 5 5 2 3 ...
## $ raw_timestamp_part_1 : int 1323095002 1322673067 1322673075 1322832789 1322489635 1322673149 ...
## $ raw_timestamp_part_2 : int 868349 778725 342967 560311 814776 510661 766645 54671 916313 3842 ...
## $ cvtd_timestamp : Factor w/ 11 levels "02/12/2011 13:33", ...: 5 10 10 1 6 11 11 10 3 2 ...
## $ new_window : Factor w/ 1 level "no": 1 1 1 1 1 1 1 1 1 ...
## $ num_window : int 74 431 439 194 235 504 485 440 323 664 ...
## $ roll_belt : num 123 1.02 0.87 125 1.35 -5.92 1.2 0.43 0.93 114 ...
## $ pitch_belt : num 27 4.87 1.82 -41.6 3.33 1.59 4.44 4.15 6.72 22.4 ...
## $ yaw_belt : num -4.75 -88.9 -88.5 162 -88.6 -87.7 -87.3 -88.5 -93.7 -13.1 ...
## $ total_accel_belt : int 20 4 5 17 3 4 4 4 4 18 ...
## $ kurtosis_roll_belt : logi NA NA NA NA NA NA ...
## $ kurtosis_pitch_belt : logi NA NA NA NA NA NA ...
## $ kurtosis_yaw_belt : logi NA NA NA NA NA NA ...
## $ skewness_roll_belt : logi NA NA NA NA NA NA ...
## $ skewness_roll_belt.1 : logi NA NA NA NA NA NA ...
## $ skewness_yaw_belt : logi NA NA NA NA NA NA ...
## $ max_roll_belt : logi NA NA NA NA NA NA ...
## $ max_pitch_belt : logi NA NA NA NA NA NA ...
## $ max_yaw_belt : logi NA NA NA NA NA NA ...
## $ min_roll_belt : logi NA NA NA NA NA NA ...
## $ min_pitch_belt : logi NA NA NA NA NA NA ...
## $ min_yaw_belt : logi NA NA NA NA NA NA ...
## $ amplitude_roll_belt : logi NA NA NA NA NA NA ...
## $ amplitude_pitch_belt : logi NA NA NA NA NA NA ...
## $ amplitude_yaw_belt : logi NA NA NA NA NA NA ...
## $ var_total_accel_belt : logi NA NA NA NA NA NA ...
## $ avg_roll_belt : logi NA NA NA NA NA NA ...

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## $ stddev_roll_belt : logi NA NA NA NA NA NA ...
## $ var_roll_belt : logi NA NA NA NA NA NA ...
## $ avg_pitch_belt : logi NA NA NA NA NA NA ...
## $ stddev_pitch_belt : logi NA NA NA NA NA NA ...
## $ var_pitch_belt : logi NA NA NA NA NA NA ...
## $ avg_yaw_belt : logi NA NA NA NA NA NA ...
## $ stddev_yaw_belt : logi NA NA NA NA NA NA ...
## $ var_yaw_belt : logi NA NA NA NA NA NA ...
## $ gyros_belt_x : num -0.5 -0.06 0.05 0.11 0.03 0.1 -0.06 -0.18 0.1 0.14 ...
## $ gyros_belt_y : num -0.02 -0.02 0.02 0.11 0.02 0.05 0 -0.02 0 0.11 ...
## $ gyros_belt_z : num -0.46 -0.07 0.03 -0.16 0 -0.13 0 -0.03 -0.02 -0.16 ...
## $ accel_belt_x : int -38 -13 1 46 -8 -11 -14 -10 -15 -25 ...
## $ accel_belt_y : int 69 11 -1 45 4 -16 2 -2 1 63 ...
## $ accel_belt_z : int -179 39 49 -156 27 38 35 42 32 -158 ...
## $ magnet_belt_x : int -13 43 29 169 33 31 50 39 -6 10 ...
## $ magnet_belt_y : int 581 636 631 608 566 638 622 635 600 601 ...
## $ magnet_belt_z : int -382 -309 -312 -304 -418 -291 -315 -305 -302 -330 ...
## $ roll_arm : num 40.7 0 0 -109 76.1 0 0 0 -137 -82.4 ...
## $ pitch_arm : num -27.8 0 0 55 2.76 0 0 0 11.2 -63.8 ...
## $ yaw_arm : num 178 0 0 -142 102 0 0 0 -167 -75.3 ...
## $ total_accel_arm : int 10 38 44 25 29 14 15 22 34 32 ...
## $ var_accel_arm : logi NA NA NA NA NA NA ...
## $ avg_roll_arm : logi NA NA NA NA NA NA ...
## $ stddev_roll_arm : logi NA NA NA NA NA NA ...
## $ var_roll_arm : logi NA NA NA NA NA NA ...
## $ avg_pitch_arm : logi NA NA NA NA NA NA ...
## $ stddev_pitch_arm : logi NA NA NA NA NA NA ...
## $ var_pitch_arm : logi NA NA NA NA NA NA ...
## $ avg_yaw_arm : logi NA NA NA NA NA NA ...
## $ stddev_yaw_arm : logi NA NA NA NA NA NA ...
## $ var_yaw_arm : logi NA NA NA NA NA NA ...
## $ gyros_arm_x : num -1.65 -1.17 2.1 0.22 -1.96 0.02 2.36 -3.71 0.03 0.26 ...
## $ gyros_arm_y : num 0.48 0.85 -1.36 -0.51 0.79 0.05 -1.01 1.85 -0.02 -0.5 ...
## $ gyros_arm_z : num -0.18 -0.43 1.13 0.92 -0.54 -0.07 0.89 -0.69 -0.02 0.79 ...
## $ accel_arm_x : int 16 -290 -341 -238 -197 -26 99 -98 -287 -301 ...
## $ accel_arm_y : int 38 215 245 -57 200 130 79 175 111 -42 ...
## $ accel_arm_z : int 93 -90 -87 6 -30 -19 -67 -78 -122 -80 ...
## $ magnet_arm_x : int -326 -325 -264 -173 -170 396 702 535 -367 -420 ...
## $ magnet_arm_y : int 385 447 474 257 275 176 15 215 335 294 ...
## $ magnet_arm_z : int 481 434 413 633 617 516 217 385 520 493 ...
## $ kurtosis_roll_arm : logi NA NA NA NA NA NA ...
## $ kurtosis_pitch_arm : logi NA NA NA NA NA NA ...
## $ kurtosis_yaw_arm : logi NA NA NA NA NA NA ...
## $ skewness_roll_arm : logi NA NA NA NA NA NA ...
## $ skewness_pitch_arm : logi NA NA NA NA NA NA ...
## $ skewness_yaw_arm : logi NA NA NA NA NA NA ...
## $ max_roll_arm : logi NA NA NA NA NA NA ...
## $ max_pitch_arm : logi NA NA NA NA NA NA ...
## $ max_yaw_arm : logi NA NA NA NA NA NA ...
## $ min_roll_arm : logi NA NA NA NA NA NA ...
## $ min_pitch_arm : logi NA NA NA NA NA NA ...
## $ min_yaw_arm : logi NA NA NA NA NA NA ...
## $ amplitude_roll_arm : logi NA NA NA NA NA NA ...
## $ amplitude_pitch_arm : logi NA NA NA NA NA NA ...

```

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## $ amplitude_yaw_arm      : logi  NA NA NA NA NA NA ...
## $ roll_dumbbell          : num   -17.7 54.5 57.1 43.1 -101.4 ...
## $ pitch_dumbbell         : num    25 -53.7 -51.4 -30 -53.4 ...
## $ yaw_dumbbell           : num   126.2 -75.5 -75.2 -103.3 -14.2 ...
## $ kurtosis_roll_dumbbell : logi  NA NA NA NA NA NA ...
## $ kurtosis_pitch_dumbbell: logi  NA NA NA NA NA NA ...
## $ kurtosis_yaw_dumbbell  : logi  NA NA NA NA NA NA ...
## $ skewness_roll_dumbbell : logi  NA NA NA NA NA NA ...
## $ skewness_pitch_dumbbell: logi  NA NA NA NA NA NA ...
## $ skewness_yaw_dumbbell  : logi  NA NA NA NA NA NA ...
## $ max_roll_dumbbell      : logi  NA NA NA NA NA NA ...
## $ max_pitch_dumbbell     : logi  NA NA NA NA NA NA ...
## $ max_yaw_dumbbell       : logi  NA NA NA NA NA NA ...
## $ min_roll_dumbbell      : logi  NA NA NA NA NA NA ...
## $ min_pitch_dumbbell     : logi  NA NA NA NA NA NA ...
## $ min_yaw_dumbbell       : logi  NA NA NA NA NA NA ...
## $ amplitude_roll_dumbbell: logi  NA NA NA NA NA NA ...
## [list output truncated]

```

The results from struture of data revealed that datasets contains missing values as "#DIV/0!". Replace them with mean or median.

#2. Pre-processing of datasets. Remove “NA”, “#DIV/0!” from data

```

traindata <- read.csv("trainingdata.csv", na.strings=c("NA", "#DIV/0!", ""))
write.csv(traindata, "traindata.csv")
testdata<-read.csv("testdata.csv", na.strings=c("NA", "#DIV/0!", ""))
write.csv(testdata, "testdata.csv")

```

Check dimensions for number of variables and number of observations

```

dim(traindata)

## [1] 19622   161

dim(testdata)

## [1] 20 161

```

summary of training and test data

```

summary(traindata)

##      X.1              X            user_name  raw_timestamp_part_1
##  Min.   : 1   Min.   : 1   adelmo  :3892   Min.   :1.322e+09
##  1st Qu.: 4906  1st Qu.: 4906  carlitos:3112  1st Qu.:1.323e+09
##  Median : 9812  Median : 9812  charles  :3536   Median :1.323e+09

```

```

##  Mean   : 9812   Mean   : 9812   eurico  :3070   Mean   :1.323e+09
##  3rd Qu.:14717  3rd Qu.:14717  jeremy   :3402   3rd Qu.:1.323e+09
##  Max.   :19622  Max.   :19622  pedro    :2610   Max.   :1.323e+09
##
## raw_timestamp_part_2          cvtd_timestamp  new_window  num_window
## Min.   : 294      28/11/2011 14:14: 1498  no :19216   Min.   : 1.0
## 1st Qu.:252912  05/12/2011 11:24: 1497  yes: 406    1st Qu.:222.0
## Median :496380  30/11/2011 17:11: 1440                Median :424.0
## Mean   :500656  05/12/2011 11:25: 1425                Mean   :430.6
## 3rd Qu.:751891  02/12/2011 14:57: 1380                3rd Qu.:644.0
## Max.   :998801  02/12/2011 13:34: 1375                Max.   :864.0
##           (Other)          :11007
##
## 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.:  1.7600  1st Qu.: -88.30  1st Qu.: 3.00
## Median :113.00 Median :  5.2800  Median : -13.00  Median :17.00
## Mean   :64.41   Mean   :  0.3053  Mean   : -11.21  Mean   :11.31
## 3rd Qu.:123.00 3rd Qu.: 14.9000 3rd Qu.:  12.90  3rd Qu.:18.00
## Max.   :162.00  Max.   : 60.3000  Max.   : 179.00  Max.   :29.00
##
## kurtosis_roll_belt kurtosis_pitch_belt kurtosis_yaw_belt
## Min.   :-2.121   Min.   :-2.190      Mode:logical
## 1st Qu.: -1.329  1st Qu.: -1.107     NA's:19622
## Median : -0.899  Median : -0.151
## Mean   : -0.220  Mean   :  4.334
## 3rd Qu.: -0.219  3rd Qu.:  3.178
## Max.   :33.000   Max.   : 58.000
## NA's   :19226    NA's   :19248
##
## skewness_roll_belt skewness_roll_belt.1 skewness_yaw_belt
## Min.   :-5.745   Min.   :-7.616      Mode:logical
## 1st Qu.: -0.444  1st Qu.: -1.114     NA's:19622
## Median :  0.000  Median : -0.068
## Mean   : -0.026  Mean   : -0.296
## 3rd Qu.:  0.417  3rd Qu.:  0.661
## Max.   : 3.595   Max.   :  7.348
## NA's   :19225    NA's   :19248
##
## max_roll_belt  max_pitch_belt  max_yaw_belt  min_roll_belt
## Min.   :-94.300  Min.   : 3.00     Min.   :-2.10   Min.   :-180.00
## 1st Qu.: -88.000 1st Qu.: 5.00     1st Qu.: -1.30  1st Qu.: -88.40
## Median : -5.100  Median :18.00     Median : -0.90  Median : -7.85
## Mean   : -6.667  Mean   :12.92     Mean   : -0.22  Mean   : -10.44
## 3rd Qu.: 18.500  3rd Qu.:19.00     3rd Qu.: -0.20  3rd Qu.:  9.05
## Max.   :180.000  Max.   :30.00     Max.   : 33.00  Max.   : 173.00
## NA's   :19216    NA's   :19216    NA's   :19226  NA's   :19216
##
## min_pitch_belt min_yaw_belt  amplitude_roll_belt amplitude_pitch_belt
## Min.   : 0.00   Min.   :-2.10   Min.   : 0.000  Min.   : 0.000
## 1st Qu.: 3.00   1st Qu.: -1.30  1st Qu.: 0.300  1st Qu.: 1.000
## Median :16.00   Median : -0.90  Median : 1.000  Median : 1.000
## Mean   :10.76   Mean   : -0.22  Mean   : 3.769  Mean   : 2.167
## 3rd Qu.:17.00   3rd Qu.: -0.20  3rd Qu.: 2.083  3rd Qu.: 2.000
## Max.   :23.00   Max.   : 33.00  Max.   :360.000  Max.   :12.000
## NA's   :19216   NA's   :19226  NA's   :19216  NA's   :19216
##
## amplitude_yaw_belt var_total_accel_belt avg_roll_belt stddev_roll_belt
## Min.   :0       Min.   : 0.000   Min.   :-27.40  Min.   : 0.000

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```

## 1st Qu.:0          1st Qu.: 0.100      1st Qu.: 1.10      1st Qu.: 0.200
## Median :0          Median : 0.200      Median :116.35     Median : 0.400
## Mean   :0          Mean   : 0.926      Mean   : 68.06      Mean   : 1.337
## 3rd Qu.:0          3rd Qu.: 0.300      3rd Qu.:123.38     3rd Qu.: 0.700
## Max.   :0          Max.   :16.500      Max.   :157.40      Max.   :14.200
## NA's   :19226      NA's   :19216      NA's   :19216      NA's   :19216
## var_roll_belt    avg_pitch_belt stddev_pitch_belt var_pitch_belt
## Min.   : 0.000      Min.   :-51.400      Min.   :0.000      Min.   : 0.000
## 1st Qu.: 0.000      1st Qu.: 2.025      1st Qu.:0.200      1st Qu.: 0.000
## Median : 0.100      Median : 5.200      Median :0.400      Median : 0.100
## Mean   : 7.699      Mean   : 0.520      Mean   :0.603      Mean   : 0.766
## 3rd Qu.: 0.500      3rd Qu.:15.775      3rd Qu.:0.700      3rd Qu.: 0.500
## Max.   :200.700      Max.   :59.700      Max.   :4.000      Max.   :16.200
## NA's   :19216      NA's   :19216      NA's   :19216      NA's   :19216
## avg_yaw_belt    stddev_yaw_belt var_yaw_belt
## Min.   :-138.300     Min.   : 0.000      Min.   : 0.000
## 1st Qu.: -88.175     1st Qu.: 0.100      1st Qu.: 0.010
## Median : -6.550      Median : 0.300      Median : 0.090
## Mean   : -8.831      Mean   : 1.341      Mean   : 107.487
## 3rd Qu.: 14.125      3rd Qu.: 0.700      3rd Qu.: 0.475
## Max.   :173.500      Max.   :176.600      Max.   :31183.240
## NA's   :19216      NA's   :19216      NA's   :19216
## gyros_belt_x    gyros_belt_y    gyros_belt_z
## Min.   :-1.0400000   Min.   :-0.64000   Min.   :-1.4600
## 1st Qu.: -0.0300000  1st Qu.: 0.00000   1st Qu.: -0.2000
## Median : 0.0300000   Median : 0.02000   Median :-0.1000
## Mean   : -0.005592   Mean   : 0.03959   Mean   : -0.1305
## 3rd Qu.: 0.1100000   3rd Qu.: 0.11000   3rd Qu.: -0.0200
## Max.   : 2.2200000   Max.   : 0.64000   Max.   : 1.6200
##
## accel_belt_x    accel_belt_y    accel_belt_z    magnet_belt_x
## Min.   :-120.0000   Min.   :-69.00     Min.   :-275.00   Min.   :-52.0
## 1st Qu.: -21.0000   1st Qu.:  3.00     1st Qu.: -162.00  1st Qu.:  9.0
## Median : -15.0000   Median : 35.00     Median :-152.00  Median : 35.0
## Mean   : -5.595     Mean   : 30.15     Mean   : -72.59   Mean   : 55.6
## 3rd Qu.: -5.000     3rd Qu.: 61.00     3rd Qu.:  27.00   3rd Qu.: 59.0
## Max.   : 85.0000    Max.   :164.00     Max.   : 105.00   Max.   :485.0
##
## 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.: -31.77   1st Qu.: -25.900
## Median :601.0       Median : -320.0   Median :  0.00     Median : 0.000
## Mean   :593.7       Mean   : -345.5   Mean   : 17.83     Mean   : -4.612
## 3rd Qu.:610.0       3rd Qu.: -306.0   3rd Qu.:  77.30   3rd Qu.: 11.200
## Max.   :673.0       Max.   : 293.0    Max.   : 180.00   Max.   : 88.500
##
## yaw_arm         total_accel_arm var_accel_arm avg_roll_arm
## Min.   :-180.00000  Min.   : 1.00     Min.   : 0.00     Min.   :-166.67
## 1st Qu.: -43.1000   1st Qu.:17.00    1st Qu.: 9.03     1st Qu.: -38.37
## Median :  0.00000   Median :27.00    Median : 40.61     Median : 0.00
## Mean   : -0.6188    Mean   :25.51    Mean   : 53.23     Mean   : 12.68
## 3rd Qu.: 45.8750    3rd Qu.:33.00    3rd Qu.: 75.62   3rd Qu.: 76.33
## Max.   :180.00000   Max.   :66.00    Max.   :331.70   Max.   : 163.33
## NA's   :19216      NA's   :19216

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##  stddev_roll_arm    var_roll_arm      avg_pitch_arm      stddev_pitch_arm
##  Min.   : 0.000   Min.   : 0.000   Min.   :-81.773   Min.   : 0.000
##  1st Qu.: 1.376   1st Qu.: 1.898   1st Qu.:-22.770   1st Qu.: 1.642
##  Median : 5.702   Median : 32.517   Median : 0.000   Median : 8.133
##  Mean   : 11.201  Mean   : 417.264  Mean   : -4.901  Mean   :10.383
##  3rd Qu.: 14.921  3rd Qu.: 222.647  3rd Qu.: 8.277   3rd Qu.:16.327
##  Max.   :161.964  Max.   :26232.208  Max.   : 75.659  Max.   :43.412
##  NA's   :19216    NA's   :19216    NA's   :19216    NA's   :19216
##  var_pitch_arm     avg_yaw_arm      stddev_yaw_arm
##  Min.   : 0.000   Min.   :-173.440  Min.   : 0.000
##  1st Qu.: 2.697   1st Qu.: -29.198  1st Qu.: 2.577
##  Median : 66.146  Median : 0.000   Median : 16.682
##  Mean   : 195.864  Mean   : 2.359   Mean   : 22.270
##  3rd Qu.: 266.576  3rd Qu.: 38.185  3rd Qu.: 35.984
##  Max.   :1884.565  Max.   :152.000  Max.   :177.044
##  NA's   :19216    NA's   :19216    NA's   :19216
##  var_yaw_arm       gyros_arm_x     gyros_arm_y
##  Min.   : 0.000   Min.   :-6.37000  Min.   :-3.4400
##  1st Qu.: 6.642   1st Qu.: -1.33000 1st Qu.: -0.8000
##  Median : 278.309  Median : 0.08000  Median : -0.2400
##  Mean   : 1055.933  Mean   : 0.04277  Mean   : -0.2571
##  3rd Qu.: 1294.850  3rd Qu.: 1.57000  3rd Qu.: 0.1400
##  Max.   :31344.568  Max.   : 4.87000  Max.   : 2.8400
##  NA's   :19216
##  gyros_arm_z       accel_arm_x    accel_arm_y    accel_arm_z
##  Min.   :-2.3300  Min.   :-404.00  Min.   :-318.0   Min.   :-636.00
##  1st Qu.:-0.0700  1st Qu.:-242.00 1st Qu.:-54.0   1st Qu.:-143.00
##  Median : 0.2300  Median : -44.00  Median : 14.0   Median : -47.00
##  Mean   : 0.2695  Mean   : -60.24  Mean   : 32.6   Mean   : -71.25
##  3rd Qu.: 0.7200  3rd Qu.: 84.00  3rd Qu.: 139.0  3rd Qu.: 23.00
##  Max.   : 3.0200  Max.   : 437.00  Max.   : 308.0  Max.   : 292.00
##
##  magnet_arm_x     magnet_arm_y   magnet_arm_z   kurtosis_roll_arm
##  Min.   :-584.0   Min.   :-392.0   Min.   :-597.0   Min.   :-1.809
##  1st Qu.:-300.0   1st Qu.: -9.0   1st Qu.: 131.2   1st Qu.:-1.345
##  Median : 289.0   Median : 202.0   Median : 444.0   Median : -0.894
##  Mean   : 191.7   Mean   : 156.6   Mean   : 306.5   Mean   : -0.366
##  3rd Qu.: 637.0   3rd Qu.: 323.0   3rd Qu.: 545.0   3rd Qu.:-0.038
##  Max.   : 782.0   Max.   : 583.0   Max.   : 694.0   Max.   : 21.456
##  NA's   :19294
##  kurtosis_pictch_arm kurtosis_yaw_arm skewness_roll_arm skewness_pitch_arm
##  Min.   :-2.084   Min.   :-2.103   Min.   :-2.541   Min.   :-4.565
##  1st Qu.:-1.280   1st Qu.:-1.220   1st Qu.:-0.561   1st Qu.:-0.618
##  Median :-1.010   Median :-0.733   Median : 0.040   Median : -0.035
##  Mean   :-0.542   Mean   : 0.406   Mean   : 0.068   Mean   : -0.065
##  3rd Qu.:-0.379   3rd Qu.: 0.115   3rd Qu.: 0.671   3rd Qu.: 0.454
##  Max.   :19.751   Max.   :56.000   Max.   : 4.394   Max.   : 3.043
##  NA's   :19296    NA's   :19227    NA's   :19293    NA's   :19296
##  skewness_yaw_arm max_roll_arm   max_pictch_arm  max_yaw_arm
##  Min.   :-6.708   Min.   :-73.100  Min.   :-173.000  Min.   : 4.00
##  1st Qu.:-0.743   1st Qu.: -0.175  1st Qu.: -1.975  1st Qu.:29.00
##  Median :-0.133   Median :  4.950   Median : 23.250   Median :34.00
##  Mean   :-0.229   Mean   : 11.236  Mean   : 35.751   Mean   :35.46
##  3rd Qu.: 0.344   3rd Qu.: 26.775  3rd Qu.: 95.975  3rd Qu.:41.00

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##  Max.    : 7.483   Max.    : 85.500   Max.    : 180.000   Max.    :65.00
##  NA's    :19227   NA's    :19216   NA's    :19216       NA's    :19216
##  min_roll_arm min_pitch_arm min_yaw_arm amplitude_roll_arm
##  Min.    :-89.10  Min.    :-180.00  Min.    : 1.00    Min.    : 0.000
##  1st Qu.:-41.98  1st Qu.:-72.62  1st Qu.: 8.00    1st Qu.: 5.425
##  Median :-22.45  Median :-33.85  Median :13.00    Median : 28.450
##  Mean    :-21.22  Mean    :-33.92  Mean    :14.66    Mean    : 32.452
##  3rd Qu.: 0.00   3rd Qu.: 0.00   3rd Qu.:19.00    3rd Qu.: 50.960
##  Max.    : 66.40  Max.    :152.00  Max.    :38.00    Max.    :119.500
##  NA's    :19216   NA's    :19216   NA's    :19216       NA's    :19216
##  amplitude_pitch_arm amplitude_yaw_arm roll_dumbbell pitch_dumbbell
##  Min.    : 0.000   Min.    : 0.00   Min.    :-153.71  Min.    :-149.59
##  1st Qu.: 9.925   1st Qu.:13.00   1st Qu.: -18.49  1st Qu.: -40.89
##  Median : 54.900   Median :22.00   Median : 48.17    Median : -20.96
##  Mean    : 69.677   Mean    :20.79   Mean    : 23.84    Mean    : -10.78
##  3rd Qu.:115.175   3rd Qu.:28.75   3rd Qu.: 67.61    3rd Qu.: 17.50
##  Max.    :360.000   Max.    :52.00   Max.    :153.55    Max.    : 149.40
##  NA's    :19216   NA's    :19216
##  yaw_dumbbell kurtosis_roll_dumbbell kurtosis_pictch_dumbbell
##  Min.    :-150.871  Min.    :-2.174   Min.    :-2.200
##  1st Qu.: -77.644  1st Qu.:-0.682   1st Qu.:-0.721
##  Median : -3.324   Median :-0.033   Median :-0.133
##  Mean    :  1.674   Mean    : 0.452   Mean    : 0.286
##  3rd Qu.: 79.643   3rd Qu.: 0.940   3rd Qu.: 0.584
##  Max.    :154.952   Max.    :54.998   Max.    :55.628
##  NA's    :19221   NA's    :19218
##  kurtosis_yaw_dumbbell skewness_roll_dumbbell skewness_pitch_dumbbell
##  Mode:logical      Min.    :-7.384   Min.    :-7.447
##  NA's:19622        1st Qu.:-0.581   1st Qu.:-0.526
##  Median : -0.076   Median :-0.091
##  Mean    : -0.115   Mean    : -0.035
##  3rd Qu.: 0.400   3rd Qu.: 0.505
##  Max.    : 1.958   Max.    : 3.769
##  NA's    :19220   NA's    :19217
##  skewness_yaw_dumbbell max_roll_dumbbell max_picth_dumbbell
##  Mode:logical      Min.    :-70.10   Min.    :-112.90
##  NA's:19622        1st Qu.:-27.15   1st Qu.: -66.70
##  Median : 14.85    Median : 40.05
##  Mean    : 13.76    Mean    : 32.75
##  3rd Qu.: 50.58    3rd Qu.: 133.22
##  Max.    :137.00    Max.    :155.00
##  NA's    :19216   NA's    :19216
##  max_yaw_dumbbell min_roll_dumbbell min_pitch_dumbbell min_yaw_dumbbell
##  Min.    :-2.20    Min.    :-149.60  Min.    :-147.00  Min.    :-2.20
##  1st Qu.:-0.70    1st Qu.:-59.67  1st Qu.: -91.80  1st Qu.:-0.70
##  Median : 0.00    Median :-43.55  Median : -66.15  Median : 0.00
##  Mean    : 0.45    Mean    :-41.24  Mean    : -33.18  Mean    : 0.45
##  3rd Qu.: 0.90    3rd Qu.:-25.20  3rd Qu.:  21.20  3rd Qu.: 0.90
##  Max.    :55.00    Max.    : 73.20  Max.    :120.90  Max.    :55.00
##  NA's    :19221   NA's    :19216   NA's    :19216       NA's    :19221
##  amplitude_roll_dumbbell amplitude_pitch_dumbbell amplitude_yaw_dumbbell
##  Min.    : 0.00    Min.    : 0.00   Min.    :0
##  1st Qu.: 14.97    1st Qu.:17.06   1st Qu.:0
##  Median : 35.05    Median :41.73   Median :0

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##  Mean   : 55.00          Mean   : 65.93          Mean   :0
## 3rd Qu.: 81.04          3rd Qu.: 99.55          3rd Qu.:0
##  Max.   :256.48          Max.   :273.59          Max.   :0
## NA's    :19216           NA's    :19216           NA's    :19221
## total_accel_dumbbell var_accel_dumbbell avg_roll_dumbbell
##  Min.   : 0.00          Min.   : 0.000          Min.   :-128.96
## 1st Qu.: 4.00           1st Qu.: 0.378          1st Qu.: -12.33
##  Median :10.00           Median : 1.000          Median : 48.23
##  Mean   :13.72           Mean   : 4.388          Mean   : 23.86
## 3rd Qu.:19.00           3rd Qu.: 3.434          3rd Qu.: 64.37
##  Max.   :58.00           Max.   :230.428         Max.   :125.99
## NA's    :19216           NA's    :19216           NA's    :19216
## stddev_roll_dumbbell var_roll_dumbbell avg_pitch_dumbbell
##  Min.   : 0.000          Min.   : 0.00          Min.   :-70.73
## 1st Qu.: 4.639           1st Qu.: 21.52          1st Qu.: -42.00
##  Median :12.204           Median : 148.95         Median : -19.91
##  Mean   :20.761           Mean   :1020.27         Mean   : -12.33
## 3rd Qu.:26.356           3rd Qu.: 694.65          3rd Qu.: 13.21
##  Max.   :123.778          Max.   :15321.01        Max.   : 94.28
## NA's    :19216           NA's    :19216           NA's    :19216
## stddev_pitch_dumbbell var_pitch_dumbbell avg_yaw_dumbbell
##  Min.   : 0.000          Min.   : 0.00          Min.   :-117.950
## 1st Qu.: 3.482           1st Qu.: 12.12          1st Qu.: -76.696
##  Median : 8.089           Median : 65.44          Median : -4.505
##  Mean   :13.147           Mean   :350.31          Mean   : 0.202
## 3rd Qu.:19.238           3rd Qu.: 370.11         3rd Qu.: 71.234
##  Max.   :82.680           Max.   :6836.02         Max.   :134.905
## NA's    :19216           NA's    :19216           NA's    :19216
## stddev_yaw_dumbbell var_yaw_dumbbell gyros_dumbbell_x
##  Min.   : 0.000          Min.   : 0.00          Min.   :-204.0000
## 1st Qu.: 3.885           1st Qu.: 15.09          1st Qu.: -0.0300
##  Median :10.264           Median :105.35          Median : 0.1300
##  Mean   :16.647           Mean   :589.84          Mean   : 0.1611
## 3rd Qu.:24.674           3rd Qu.: 608.79         3rd Qu.: 0.3500
##  Max.   :107.088          Max.   :11467.91        Max.   : 2.2200
## NA's    :19216           NA's    :19216           NA's    :19216
## gyros_dumbbell_y gyros_dumbbell_z accel_dumbbell_x accel_dumbbell_y
##  Min.   :-2.10000          Min.   :-2.380          Min.   :-419.00      Min.   :-189.00
## 1st Qu.:-0.14000          1st Qu.: -0.310         1st Qu.: -50.00      1st Qu.: -8.00
##  Median : 0.03000          Median : -0.130         Median : -8.00       Median : 41.50
##  Mean   : 0.04606          Mean   : -0.129         Mean   : -28.62      Mean   : 52.63
## 3rd Qu.: 0.21000          3rd Qu.:  0.030         3rd Qu.: 11.00       3rd Qu.: 111.00
##  Max.   :52.00000          Max.   :317.000         Max.   : 235.00      Max.   : 315.00
##
##  accel_dumbbell_z magnet_dumbbell_x magnet_dumbbell_y magnet_dumbbell_z
##  Min.   :-334.00           Min.   :-643.0          Min.   :-3600         Min.   :-262.00
## 1st Qu.:-142.00           1st Qu.:-535.0          1st Qu.: 231          1st Qu.: -45.00
##  Median : -1.00            Median :-479.0          Median : 311          Median : 13.00
##  Mean   : -38.32            Mean   :-328.5          Mean   : 221          Mean   : 46.05
## 3rd Qu.: 38.00             3rd Qu.:-304.0          3rd Qu.: 390          3rd Qu.: 95.00
##  Max.   : 318.00            Max.   :592.0           Max.   : 633          Max.   : 452.00
##
##  roll_forearm     pitch_forearm     yaw_forearm
##  Min.   :-180.00000        Min.   :-72.50          Min.   :-180.00

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## 1st Qu.: -0.7375 1st Qu.: 0.00 1st Qu.: -68.60
## Median : 21.7000 Median : 9.24 Median : 0.00
## Mean : 33.8265 Mean : 10.71 Mean : 19.21
## 3rd Qu.: 140.0000 3rd Qu.: 28.40 3rd Qu.: 110.00
## Max. : 180.0000 Max. : 89.80 Max. : 180.00
##
## kurtosis_roll_forearm kurtosis_pictch_forearm kurtosis_yaw_forearm
## Min. :-1.879 Min. :-2.098 Mode:logical
## 1st Qu.:-1.398 1st Qu.:-1.376 NA's:19622
## Median :-1.119 Median :-0.890
## Mean :-0.689 Mean : 0.419
## 3rd Qu.:-0.618 3rd Qu.: 0.054
## Max. :40.060 Max. :33.626
## NA's :19300 NA's :19301
## skewness_roll_forearm skewness_pitch_forearm skewness_yaw_forearm
## Min. :-2.297 Min. :-5.241 Mode:logical
## 1st Qu.:-0.402 1st Qu.:-0.881 NA's:19622
## Median : 0.003 Median :-0.156
## Mean :-0.009 Mean : -0.223
## 3rd Qu.: 0.370 3rd Qu.: 0.514
## Max. : 5.856 Max. : 4.464
## NA's :19299 NA's :19301
## max_roll_forearm max_pictch_forearm max_yaw_forearm min_roll_forearm
## Min. :-66.60 Min. :-151.00 Min. :-1.900 Min. :-72.500
## 1st Qu.: 0.00 1st Qu.: 0.00 1st Qu.:-1.400 1st Qu.: -6.075
## Median : 26.80 Median : 113.00 Median :-1.100 Median : 0.000
## Mean : 24.49 Mean : 81.49 Mean :-0.689 Mean : -0.167
## 3rd Qu.: 45.95 3rd Qu.: 174.75 3rd Qu.:-0.600 3rd Qu.: 12.075
## Max. : 89.80 Max. : 180.00 Max. :40.100 Max. : 62.100
## NA's :19216 NA's :19216 NA's :19300 NA's :19216
## min_pitch_forearm min_yaw_forearm amplitude_roll_forearm
## Min. :-180.00 Min. :-1.900 Min. : 0.000
## 1st Qu.:-175.00 1st Qu.:-1.400 1st Qu.: 1.125
## Median : -61.00 Median :-1.100 Median : 17.770
## Mean : -57.57 Mean :-0.689 Mean : 24.653
## 3rd Qu.: 0.00 3rd Qu.:-0.600 3rd Qu.: 39.875
## Max. : 167.00 Max. :40.100 Max. :126.000
## NA's :19216 NA's :19300 NA's :19216
## amplitude_pitch_forearm amplitude_yaw_forearm total_accel_forearm
## Min. : 0.0 Min. :0 Min. : 0.00
## 1st Qu.: 2.0 1st Qu.:0 1st Qu.: 29.00
## Median : 83.7 Median :0 Median : 36.00
## Mean :139.1 Mean :0 Mean : 34.72
## 3rd Qu.:350.0 3rd Qu.:0 3rd Qu.: 41.00
## Max. :360.0 Max. :0 Max. :108.00
## NA's :19216 NA's :19300
## var_accel_forearm avg_roll_forearm stddev_roll_forearm
## Min. : 0.000 Min. :-177.234 Min. : 0.000
## 1st Qu.: 6.759 1st Qu.: -0.909 1st Qu.: 0.428
## Median : 21.165 Median : 11.172 Median : 8.030
## Mean : 33.502 Mean : 33.165 Mean : 41.986
## 3rd Qu.: 51.240 3rd Qu.: 107.132 3rd Qu.: 85.373
## Max. :172.606 Max. : 177.256 Max. :179.171
## NA's :19216 NA's :19216 NA's :19216

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##  var_roll_forearm  avg_pitch_forearm stddev_pitch_forearm
##  Min.    : 0.00   Min.   :-68.17   Min.   : 0.000
##  1st Qu.: 0.18   1st Qu.: 0.00    1st Qu.: 0.336
##  Median : 64.48  Median : 12.02   Median : 5.516
##  Mean   : 5274.10 Mean   : 11.79   Mean   : 7.977
##  3rd Qu.: 7289.08 3rd Qu.: 28.48   3rd Qu.: 12.866
##  Max.   :32102.24 Max.   : 72.09   Max.   : 47.745
##  NA's   :19216    NA's   :19216   NA's   :19216
##  var_pitch_forearm avg_yaw_forearm stddev_yaw_forearm
##  Min.    : 0.000  Min.   :-155.06  Min.   : 0.000
##  1st Qu.: 0.113  1st Qu.: -26.26  1st Qu.: 0.524
##  Median : 30.425 Median :  0.00   Median : 24.743
##  Mean   : 139.593 Mean   : 18.00   Mean   : 44.854
##  3rd Qu.: 165.532 3rd Qu.: 85.79   3rd Qu.: 85.817
##  Max.   :2279.617 Max.   : 169.24  Max.   : 197.508
##  NA's   :19216    NA's   :19216   NA's   :19216
##  var_yaw_forearm gyros_forearm_x gyros_forearm_y
##  Min.    : 0.00   Min.   :-22.0000  Min.   : -7.02000
##  1st Qu.: 0.27   1st Qu.: -0.220  1st Qu.: -1.46000
##  Median : 612.21 Median :  0.050  Median :  0.03000
##  Mean   : 4639.85 Mean   : 0.158  Mean   : 0.07517
##  3rd Qu.: 7368.41 3rd Qu.: 0.560  3rd Qu.: 1.62000
##  Max.   :39009.33 Max.   : 3.970  Max.   :311.00000
##  NA's   :19216
##  gyros_forearm_z accel_forearm_x accel_forearm_y accel_forearm_z
##  Min.   :-8.0900  Min.   :-498.00  Min.   :-632.0  Min.   :-446.00
##  1st Qu.: -0.1800 1st Qu.: -178.00 1st Qu.:  57.0  1st Qu.: -182.00
##  Median :  0.0800 Median : -57.00  Median : 201.0  Median : -39.00
##  Mean   :  0.1512 Mean   : -61.65  Mean   : 163.7  Mean   : -55.29
##  3rd Qu.:  0.4900 3rd Qu.:  76.00  3rd Qu.: 312.0  3rd Qu.:  26.00
##  Max.   :231.0000 Max.   : 477.00  Max.   : 923.0  Max.   : 291.00
##
##  magnet_forearm_x magnet_forearm_y magnet_forearm_z classe
##  Min.   :-1280.0  Min.   :-896.0  Min.   :-973.0  A:5580
##  1st Qu.: -616.0  1st Qu.:  2.0   1st Qu.: 191.0   B:3797
##  Median : -378.0  Median : 591.0  Median : 511.0   C:3422
##  Mean   : -312.6  Mean   : 380.1  Mean   : 393.6   D:3216
##  3rd Qu.: -73.0   3rd Qu.: 737.0  3rd Qu.: 653.0   E:3607
##  Max.   : 672.0   Max.   :1480.0  Max.   :1090.0
##
summary(testdata)

##          X.1              X           user_name raw_timestamp_part_1
##  Min.   : 1.00   Min.   : 1.00   adelmo :1   Min.   :1.322e+09
##  1st Qu.: 5.75   1st Qu.: 5.75   carlitos:3  1st Qu.:1.323e+09
##  Median :10.50   Median :10.50   charles :1   Median :1.323e+09
##  Mean   :10.50   Mean   :10.50   eurico  :4   Mean   :1.323e+09
##  3rd Qu.:15.25   3rd Qu.:15.25  jeremy  :8   3rd Qu.:1.323e+09
##  Max.   :20.00   Max.   :20.00   pedro   :3   Max.   :1.323e+09
##
##  raw_timestamp_part_2      cvtd_timestamp new_window num_window
##  Min.   : 36553   30/11/2011 17:11:4   no:20      Min.   : 48.0
##  1st Qu.:268655  05/12/2011 11:24:3   no:20      1st Qu.:250.0
##  Median :530706  30/11/2011 17:12:3   no:20      Median :384.5

```

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##  Mean   :512167      05/12/2011 14:23:2      Mean   :379.6
##  3rd Qu.:787738     28/11/2011 14:14:2      3rd Qu.:467.0
##  Max.   :920315     02/12/2011 13:33:1      Max.   :859.0
##                (Other)      :5
##    roll_belt      pitch_belt      yaw_belt      total_accel_belt
##  Min.   :-5.9200    Min.   :-41.600    Min.   :-93.70    Min.   : 2.00
##  1st Qu.: 0.9075    1st Qu.:  3.013    1st Qu.: -88.62   1st Qu.: 3.00
##  Median : 1.1100    Median :  4.655    Median : -87.85   Median : 4.00
##  Mean   : 31.3055   Mean   :  5.824    Mean   : -59.30   Mean   : 7.55
##  3rd Qu.: 32.5050   3rd Qu.:  6.135    3rd Qu.: -63.50   3rd Qu.: 8.00
##  Max.   :129.0000   Max.   : 27.800    Max.   :162.00    Max.   :21.00
##
##    kurtosis_roll_belt kurtosis_pitch_belt kurtosis_yaw_belt
##  Mode:logical        Mode:logical        Mode:logical
##  NA's:20             NA's:20           NA's:20
##
##    skewness_roll_belt skewness_roll_belt.1 skewness_yaw_belt max_roll_belt
##  Mode:logical        Mode:logical        Mode:logical        Mode:logical
##  NA's:20             NA's:20           NA's:20           NA's:20
##
##    max_pitch_belt max_yaw_belt min_roll_belt min_pitch_belt
##  Mode:logical       Mode:logical       Mode:logical       Mode:logical
##  NA's:20            NA's:20           NA's:20           NA's:20
##
##    min_yaw_belt amplitude_roll_belt amplitude_pitch_belt
##  Mode:logical       Mode:logical       Mode:logical
##  NA's:20            NA's:20           NA's:20
##
##    amplitude_yaw_belt var_total_accel_belt avg_roll_belt stddev_roll_belt
##  Mode:logical       Mode:logical       Mode:logical       Mode:logical
##  NA's:20            NA's:20           NA's:20           NA's:20
##
##    var_roll_belt avg_pitch_belt stddev_pitch_belt var_pitch_belt
##  Mode:logical       Mode:logical       Mode:logical       Mode:logical

```

```

##  NA's:20      NA's:20      NA's:20      NA's:20
##
##
##
##
##  avg_yaw_belt  stddev_yaw_belt var_yaw_belt    gyros_belt_x
##  Mode:logical   Mode:logical   Mode:logical   Min.   :-0.500
##  NA's:20        NA's:20       NA's:20       1st Qu.:-0.070
##                                         Median : 0.020
##                                         Mean   :-0.045
##                                         3rd Qu.: 0.070
##                                         Max.   : 0.240
##
##  gyros_belt_y   gyros_belt_z   accel_belt_x   accel_belt_y
##  Min.   :-0.050  Min.   :-0.4800  Min.   :-48.00  Min.   :-16.00
##  1st Qu.:-0.005 1st Qu.:-0.1375 1st Qu.:-19.00 1st Qu.: 2.00
##  Median : 0.000  Median :-0.0250  Median :-13.00  Median : 4.50
##  Mean   : 0.010  Mean   :-0.1005  Mean   :-13.50  Mean   : 18.35
##  3rd Qu.: 0.020  3rd Qu.: 0.0000  3rd Qu.: -8.75  3rd Qu.: 25.50
##  Max.   : 0.110  Max.   : 0.0500  Max.   : 46.00  Max.   : 72.00
##
##  accel_belt_z   magnet_belt_x  magnet_belt_y  magnet_belt_z
##  Min.   :-187.00  Min.   :-13.00   Min.   :566.0   Min.   :-426.0
##  1st Qu.: -24.00  1st Qu.: 5.50   1st Qu.:578.5  1st Qu.:-398.5
##  Median : 27.00   Median :33.50   Median :600.5   Median :-313.5
##  Mean   : -17.60  Mean   :35.15   Mean   :601.5   Mean   :-346.9
##  3rd Qu.: 38.25   3rd Qu.:46.25   3rd Qu.:631.2  3rd Qu.:-305.0
##  Max.   : 49.00   Max.   :169.00  Max.   :638.0   Max.   :-291.0
##
##  roll_arm       pitch_arm     yaw_arm       total_accel_arm
##  Min.   :-137.00  Min.   :-63.800  Min.   :-167.00  Min.   : 3.00
##  1st Qu.:  0.00   1st Qu.:-9.188  1st Qu.:-60.15  1st Qu.:20.25
##  Median :  0.00   Median : 0.000   Median : 0.00   Median :29.50
##  Mean   : 16.42   Mean   :-3.950   Mean   :-2.80   Mean   :26.40
##  3rd Qu.: 71.53   3rd Qu.: 3.465   3rd Qu.: 25.50  3rd Qu.:33.25
##  Max.   : 152.00  Max.   : 55.000  Max.   :178.00  Max.   :44.00
##
##  var_accel_arm  avg_roll_arm  stddev_roll_arm var_roll_arm
##  Mode:logical   Mode:logical   Mode:logical   Mode:logical
##  NA's:20        NA's:20       NA's:20       NA's:20
##
##
##
##
##  avg_pitch_arm  stddev_pitch_arm var_pitch_arm  avg_yaw_arm
##  Mode:logical   Mode:logical   Mode:logical   Mode:logical
##  NA's:20        NA's:20       NA's:20       NA's:20
##
##
##
##
##
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##  stddev_yaw_arm var_yaw_arm      gyros_arm_x      gyros_arm_y
##  Mode:logical   Mode:logical   Min.   :-3.710   Min.   :-2.0900
##  NA's:20        NA's:20       1st Qu.:-0.645   1st Qu.:-0.6350
##                                         Median : 0.020   Median :-0.0400
##                                         Mean   : 0.077   Mean   :-0.1595
##                                         3rd Qu.: 1.248   3rd Qu.: 0.2175
##                                         Max.   : 3.660   Max.   : 1.8500
##
##  gyros_arm_z      accel_arm_x      accel_arm_y      accel_arm_z
##  Min.   :-0.6900   Min.   :-341.0   Min.   :-65.00   Min.   :-404.00
##  1st Qu.:-0.1800   1st Qu.:-277.0   1st Qu.: 52.25   1st Qu.:-128.50
##  Median :-0.0250   Median :-194.5   Median :112.00   Median : -83.50
##  Mean   : 0.1205   Mean   :-134.6   Mean   :103.10   Mean   :-87.85
##  3rd Qu.: 0.5650   3rd Qu.:  5.5    3rd Qu.:168.25   3rd Qu.: -27.25
##  Max.   : 1.1300   Max.   :106.0    Max.   :245.00   Max.   :  93.00
##
##  magnet_arm_x     magnet_arm_y     magnet_arm_z     kurtosis_roll_arm
##  Min.   :-428.00   Min.   :-307.0   Min.   :-499.0   Mode:logical
##  1st Qu.:-373.75   1st Qu.: 205.2   1st Qu.: 403.0   NA's:20
##  Median :-265.00   Median : 291.0   Median : 476.5
##  Mean   : -38.95   Mean   : 239.4   Mean   : 369.8
##  3rd Qu.: 250.50   3rd Qu.: 358.8   3rd Qu.: 517.0
##  Max.   : 750.00   Max.   :474.0    Max.   : 633.0
##
##  kurtosis_pitch_arm kurtosis_yaw_arm skewness_roll_arm skewness_pitch_arm
##  Mode:logical      Mode:logical      Mode:logical      Mode:logical
##  NA's:20           NA's:20          NA's:20          NA's:20
##
##  skewness_yaw_arm max_roll_arm    max_pitch_arm   max_yaw_arm
##  Mode:logical      Mode:logical      Mode:logical      Mode:logical
##  NA's:20           NA's:20          NA's:20          NA's:20
##
##  min_roll_arm     min_pitch_arm   min_yaw_arm    amplitude_roll_arm
##  Mode:logical      Mode:logical      Mode:logical      Mode:logical
##  NA's:20           NA's:20          NA's:20          NA's:20
##
##  amplitude_pitch_arm amplitude_yaw_arm roll_dumbbell      pitch_dumbbell
##  Mode:logical      Mode:logical      Min.   :-111.118   Min.   :-54.97
##  NA's:20           NA's:20          1st Qu.:  7.494   1st Qu.:-51.89
##                                         Median : 50.403   Median :-40.81
##                                         Mean   : 33.760   Mean   :-19.47
##                                         3rd Qu.: 58.129   3rd Qu.: 16.12

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##                                         Max.    : 123.984   Max.    : 96.87
##
##      yaw_dumbbell      kurtosis_roll_dumbbell kurtosis_pitch_dumbbell
##  Min.    :-103.3200    Mode:logical           Mode:logical
##  1st Qu.: -75.2809    NA's:20                NA's:20
##  Median  : -8.2863
##  Mean    : -0.9385
##  3rd Qu.: 55.8335
##  Max.    : 132.2337
##
##      kurtosis_yaw_dumbbell skewness_roll_dumbbell skewness_pitch_dumbbell
##  Mode:logical           Mode:logical           Mode:logical
##  NA's:20                NA's:20                NA's:20
##
##
##      skewness_yaw_dumbbell max_roll_dumbbell max_pitch_dumbbell
##  Mode:logical           Mode:logical           Mode:logical
##  NA's:20                NA's:20                NA's:20
##
##
##      max_yaw_dumbbell min_roll_dumbbell min_pitch_dumbbell min_yaw_dumbbell
##  Mode:logical           Mode:logical           Mode:logical           Mode:logical
##  NA's:20                NA's:20                NA's:20                NA's:20
##
##
##      amplitude_roll_dumbbell amplitude_pitch_dumbbell amplitude_yaw_dumbbell
##  Mode:logical           Mode:logical           Mode:logical
##  NA's:20                NA's:20                NA's:20
##
##
##      total_accel_dumbbell var_accel_dumbbell avg_roll_dumbbell
##  Min.    : 1.0          Mode:logical           Mode:logical
##  1st Qu.: 7.0          NA's:20                NA's:20
##  Median  :15.5
##  Mean    :17.2
##  3rd Qu.:29.0
##  Max.    :31.0
##
##      stddev_roll_dumbbell var_roll_dumbbell avg_pitch_dumbbell
##  Mode:logical           Mode:logical           Mode:logical
##  NA's:20                NA's:20                NA's:20
##

```

```

##
##
##
##
##  stddev_pitch_dumbbell var_pitch_dumbbell avg_yaw_dumbbell
##  Mode:logical          Mode:logical          Mode:logical
##  NA's:20                NA's:20                NA's:20
##
##
##
##
##  stddev_yaw_dumbbell var_yaw_dumbbell gyros_dumbbell_x  gyros_dumbbell_y
##  Mode:logical          Mode:logical          Min.   :-1.0300  Min.   :-1.1100
##  NA's:20                NA's:20                1st Qu.: 0.1600  1st Qu.:-0.2100
##                                         Median : 0.3600  Median : 0.0150
##                                         Mean   : 0.2690  Mean   : 0.0605
##                                         3rd Qu.: 0.4625 3rd Qu.: 0.1450
##                                         Max.   : 1.0600  Max.   : 1.9100
##
##  gyros_dumbbell_z accel_dumbbell_x  accel_dumbbell_y  accel_dumbbell_z
##  Min.   :-1.180    Min.   :-159.00   Min.   :-30.00   Min.   :-221.0
##  1st Qu.:-0.485   1st Qu.:-140.25  1st Qu.: 5.75    1st Qu.:-192.2
##  Median :-0.280   Median : -19.00   Median : 71.50   Median : -3.0
##  Mean   :-0.266   Mean   : -47.60   Mean   : 70.55   Mean   : -60.0
##  3rd Qu.:-0.165   3rd Qu.: 15.75    3rd Qu.:151.25  3rd Qu.: 76.5
##  Max.   : 1.100    Max.   : 185.00   Max.   :166.00   Max.   : 100.0
##
##  magnet_dumbbell_x magnet_dumbbell_y magnet_dumbbell_z  roll_forearm
##  Min.   :-576.0    Min.   :-558.0    Min.   :-164.00  Min.   :-176.00
##  1st Qu.:-528.0   1st Qu.: 259.5   1st Qu.: -33.00  1st Qu.: -40.25
##  Median :-508.5   Median : 316.0   Median : 49.50   Median : 94.20
##  Mean   :-304.2   Mean   : 189.3   Mean   : 71.40   Mean   : 38.66
##  3rd Qu.:-317.0   3rd Qu.: 348.2   3rd Qu.: 96.25   3rd Qu.: 143.25
##  Max.   : 523.0    Max.   : 403.0   Max.   :368.00   Max.   : 176.00
##
##  pitch_forearm      yaw_forearm      kurtosis_roll_forearm
##  Min.   :-63.500    Min.   :-168.000  Mode:logical
##  1st Qu.:-11.457   1st Qu.: -93.375 NA's:20
##  Median : 8.830    Median : -19.250
##  Mean   : 7.099    Mean   : 2.195
##  3rd Qu.: 28.500   3rd Qu.: 104.500
##  Max.   : 59.300   Max.   : 159.000
##
##  kurtosis_pitch_forearm kurtosis_yaw_forearm skewness_roll_forearm
##  Mode:logical          Mode:logical          Mode:logical
##  NA's:20                NA's:20                NA's:20
##
##
##
##
##  skewness_pitch_forearm skewness_yaw_forearm max_roll_forearm
##  Mode:logical          Mode:logical          Mode:logical

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##  NA's:20           NA's:20           NA's:20
## 
## 
## 
## 
##  max_pitch_forearm max_yaw_forearm min_roll_forearm min_pitch_forearm
##  Mode:logical      Mode:logical    Mode:logical    Mode:logical
##  NA's:20           NA's:20         NA's:20        NA's:20
## 
## 
## 
## 
##  min_yaw_forearm amplitude_roll_forearm amplitude_pitch_forearm
##  Mode:logical      Mode:logical      Mode:logical
##  NA's:20           NA's:20         NA's:20
## 
## 
## 
## 
##  amplitude_yaw_forearm total_accel_forearm var_accel_forearm
##  Mode:logical      Min.   :21.00      Mode:logical
##  NA's:20           1st Qu.:24.00     NA's:20
##                      Median :32.50
##                      Mean   :32.05
##                      3rd Qu.:36.75
##                      Max.   :47.00
## 
## 
##  avg_roll_forearm stddev_roll_forearm var_roll_forearm avg_pitch_forearm
##  Mode:logical      Mode:logical      Mode:logical    Mode:logical
##  NA's:20           NA's:20         NA's:20        NA's:20
## 
## 
## 
## 
##  stddev_pitch_forearm var_pitch_forearm avg_yaw_forearm stddev_yaw_forearm
##  Mode:logical      Mode:logical      Mode:logical    Mode:logical
##  NA's:20           NA's:20         NA's:20        NA's:20
## 
## 
## 
## 
##  var_yaw_forearm gyros_forearm_x  gyros_forearm_y  gyros_forearm_z
##  Mode:logical      Min.   :-1.0600   Min.   :-5.9700   Min.   :-1.2600
##  NA's:20           1st Qu.:-0.5850   1st Qu.:-1.2875   1st Qu.:-0.0975
##                      Median : 0.0200   Median : 0.0350   Median : 0.2300
##                      Mean   :-0.0200   Mean   :-0.0415   Mean   : 0.2610
##                      3rd Qu.: 0.2925   3rd Qu.: 2.0475   3rd Qu.: 0.7625
##                      Max.   : 1.3800   Max.   : 4.2600   Max.   : 1.8000
## 
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## accel_forearm_x accel_forearm_y accel_forearm_z magnet_forearm_x
## Min.   :-212.0   Min.   :-331.0   Min.   :-282.0   Min.   :-714.0
## 1st Qu.:-114.8   1st Qu.:  8.5    1st Qu.:-199.0   1st Qu.:-427.2
## Median :  86.0    Median :138.0    Median :-148.5    Median :-189.5
## Mean   :  38.8    Mean   :125.3    Mean   :-93.7    Mean   :-159.2
## 3rd Qu.: 166.2    3rd Qu.:268.0    3rd Qu.:-31.0    3rd Qu.: 41.5
## Max.   : 232.0    Max.   :406.0    Max.   :179.0    Max.   :532.0
##
## magnet_forearm_y magnet_forearm_z   problem_id
## Min.   :-787.0   Min.   :-32.0    Min.   : 1.00
## 1st Qu.:-328.8   1st Qu.:275.2   1st Qu.: 5.75
## Median : 487.0    Median :491.5    Median :10.50
## Mean   : 191.8    Mean   :460.2    Mean   :10.50
## 3rd Qu.: 720.8    3rd Qu.:661.5   3rd Qu.:15.25
## Max.   : 800.0    Max.   :884.0    Max.   :20.00
##
# The summary results revealed that some columns contains all "NA". So deleted columns with all missing
traindataset<-traindata[,colSums(is.na(traindata)) == 0]
testdata <-testdata[,colSums(is.na(testdata)) == 0]
# summary of training and test data after removal of NAs
summary(traindataset)

##          X.1            X      user_name raw_timestamp_part_1
## Min.   :  1   Min.   :  1   adelmo  :3892   Min.   :1.322e+09
## 1st Qu.:4906  1st Qu.:4906 carlitos:3112  1st Qu.:1.323e+09
## Median :9812   Median :9812  charles :3536   Median :1.323e+09
## Mean   :9812   Mean   :9812  eurico   :3070   Mean   :1.323e+09
## 3rd Qu.:14717  3rd Qu.:14717 jeremy   :3402   3rd Qu.:1.323e+09
## Max.   :19622  Max.   :19622  pedro    :2610   Max.   :1.323e+09
##
## raw_timestamp_part_2           cvtd_timestamp new_window num_window
## Min.   : 294   28/11/2011 14:14: 1498 no  :19216   Min.   : 1.0
## 1st Qu.:252912 05/12/2011 11:24: 1497 yes: 406   1st Qu.:222.0
## Median :496380 30/11/2011 17:11: 1440             Median :424.0
## Mean   :500656  05/12/2011 11:25: 1425             Mean   :430.6
## 3rd Qu.:751891 02/12/2011 14:57: 1380             3rd Qu.:644.0
## Max.   :998801  02/12/2011 13:34: 1375             Max.   :864.0
##                   (Other)          :11007
##
## 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.:  1.7600  1st Qu.: -88.30  1st Qu.: 3.00
## Median :113.00  Median :  5.2800  Median : -13.00  Median :17.00
## Mean   : 64.41  Mean   :  0.3053  Mean   : -11.21  Mean   :11.31
## 3rd Qu.:123.00  3rd Qu.: 14.9000 3rd Qu.:  12.90  3rd Qu.:18.00
## Max.   :162.00  Max.   : 60.3000  Max.   : 179.00  Max.   :29.00
##
## 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   :-0.005592  Mean   : 0.03959  Mean   :-0.1305
## 3rd Qu.: 0.110000  3rd Qu.: 0.11000  3rd Qu.:-0.0200
## Max.   : 2.220000  Max.   : 0.64000  Max.   : 1.6200
##

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##   accel_belt_x      accel_belt_y      accel_belt_z      magnet_belt_x
## Min.    :-120.000    Min.    :-69.00     Min.    :-275.00    Min.    :-52.0
## 1st Qu.: -21.000    1st Qu.:  3.00     1st Qu.: -162.00   1st Qu.:  9.0
## Median : -15.000    Median : 35.00     Median : -152.00   Median : 35.0
## Mean   : -5.595    Mean   : 30.15     Mean   : -72.59    Mean   : 55.6
## 3rd Qu.: -5.000    3rd Qu.: 61.00     3rd Qu.:  27.00    3rd Qu.: 59.0
## Max.    : 85.000    Max.    :164.00     Max.    : 105.00   Max.    :485.0
##
##   magnet_belt_y      magnet_belt_z      roll_arm        pitch_arm
## Min.    :354.0       Min.    :-623.0     Min.    :-180.000   Min.    :-88.800
## 1st Qu.: 581.0       1st Qu.: -375.0    1st Qu.: -31.77    1st Qu.: -25.900
## Median : 601.0       Median : -320.0    Median :  0.00     Median :  0.000
## Mean   : 593.7       Mean   : -345.5    Mean   : 17.83     Mean   : -4.612
## 3rd Qu.: 610.0       3rd Qu.: -306.0    3rd Qu.:  77.30    3rd Qu.: 11.200
## Max.    : 673.0       Max.    : 293.0     Max.    : 180.000   Max.    : 88.500
##
##   yaw_arm          total_accel_arm  gyros_arm_x      gyros_arm_y
## Min.    :-180.00000  Min.    : 1.00     Min.    :-6.37000  Min.    :-3.4400
## 1st Qu.: -43.1000   1st Qu.: 17.00    1st Qu.: -1.33000 1st Qu.: -0.8000
## Median :  0.00000   Median : 27.00    Median : 0.08000   Median : -0.2400
## Mean   : -0.6188   Mean   : 25.51    Mean   : 0.04277   Mean   : -0.2571
## 3rd Qu.:  45.8750   3rd Qu.: 33.00    3rd Qu.: 1.57000   3rd Qu.: 0.1400
## Max.    : 180.00000 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.    :-318.0    Min.    :-636.00
## 1st Qu.: -0.0700   1st Qu.: -242.00  1st Qu.: -54.0    1st Qu.: -143.00
## Median :  0.2300   Median : -44.00   Median : 14.0     Median : -47.00
## Mean   :  0.2695   Mean   : -60.24   Mean   : 32.6     Mean   : -71.25
## 3rd Qu.:  0.7200   3rd Qu.:  84.00   3rd Qu.: 139.0   3rd Qu.:  23.00
## Max.    :  3.0200   Max.    : 437.00  Max.    : 308.0   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.: -300.0     1st Qu.: -9.0     1st Qu.: 131.2    1st Qu.: -18.49
## Median :  289.0     Median : 202.0    Median : 444.0    Median :  48.17
## Mean   : 191.7      Mean   : 156.6    Mean   : 306.5    Mean   : 23.84
## 3rd Qu.: 637.0      3rd Qu.: 323.0    3rd Qu.: 545.0    3rd Qu.: 67.61
## Max.    : 782.0      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.: -40.89    1st Qu.: -77.644   1st Qu.: 4.00
## Median : -20.96    Median : -3.324    Median : 10.00
## Mean   : -10.78    Mean   : 1.674     Mean   : 13.72
## 3rd Qu.: 17.50     3rd Qu.: 79.643    3rd Qu.: 19.00
## Max.    : 149.40    Max.    : 154.952   Max.    : 58.00
##
##   gyros_dumbbell_x  gyros_dumbbell_y  gyros_dumbbell_z
## Min.    :-204.00000 Min.    :-2.10000   Min.    : -2.380
## 1st Qu.: -0.0300   1st Qu.: -0.14000   1st Qu.: -0.310
## Median :  0.1300   Median : 0.03000   Median : -0.130
## Mean   :  0.1611   Mean   : 0.04606   Mean   : -0.129
## 3rd Qu.:  0.3500   3rd Qu.: 0.21000   3rd Qu.:  0.030

```

```

##  Max.    : 2.2200   Max.    :52.00000   Max.    :317.000
##
##  accel_dumbbell_x  accel_dumbbell_y  accel_dumbbell_z  magnet_dumbbell_x
##  Min.    :-419.00   Min.    :-189.00   Min.    :-334.00   Min.    :-643.0
##  1st Qu.: -50.00   1st Qu.: -8.00    1st Qu.: -142.00  1st Qu.: -535.0
##  Median   : -8.00   Median   : 41.50    Median   : -1.00   Median   : -479.0
##  Mean     : -28.62  Mean     : 52.63    Mean     : -38.32  Mean     : -328.5
##  3rd Qu.:  11.00   3rd Qu.: 111.00   3rd Qu.:  38.00   3rd Qu.: -304.0
##  Max.    : 235.00   Max.    : 315.00   Max.    : 318.00   Max.    : 592.0
##
##  magnet_dumbbell_y  magnet_dumbbell_z  roll_forearm      pitch_forearm
##  Min.    :-3600     Min.    :-262.00   Min.    :-180.0000  Min.    :-72.50
##  1st Qu.: 231       1st Qu.: -45.00   1st Qu.: -0.7375  1st Qu.:  0.00
##  Median   : 311       Median   : 13.00    Median   : 21.7000  Median   :  9.24
##  Mean     : 221       Mean     : 46.05    Mean     : 33.8265  Mean     : 10.71
##  3rd Qu.: 390       3rd Qu.: 95.00    3rd Qu.: 140.0000 3rd Qu.: 28.40
##  Max.    : 633       Max.    : 452.00   Max.    : 180.0000  Max.    : 89.80
##
##  yaw_forearm      total_accel_forearm gyros_forearm_x
##  Min.    :-180.00   Min.    : 0.00     Min.    :-22.000
##  1st Qu.: -68.60   1st Qu.: 29.00    1st Qu.: -0.220
##  Median   : 0.00     Median   : 36.00    Median   : 0.050
##  Mean     : 19.21   Mean     : 34.72    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.    :-498.00  Min.    :-632.0
##  1st Qu.: -1.46000 1st Qu.: -0.1800  1st Qu.: -178.00 1st Qu.:  57.0
##  Median   : 0.03000 Median   : 0.0800  Median   : -57.00  Median   : 201.0
##  Mean     : 0.07517 Mean     : 0.1512  Mean     : -61.65  Mean     : 163.7
##  3rd Qu.: 1.62000  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.    :-446.00   Min.    :-1280.0  Min.    :-896.0   Min.    :-973.0
##  1st Qu.: -182.00  1st Qu.: -616.0  1st Qu.:  2.0     1st Qu.: 191.0
##  Median   : -39.00  Median   : -378.0  Median   : 591.0   Median   : 511.0
##  Mean     : -55.29  Mean     : -312.6  Mean     : 380.1   Mean     : 393.6
##  3rd Qu.:  26.00   3rd Qu.: -73.0   3rd Qu.: 737.0   3rd Qu.: 653.0
##  Max.    : 291.00   Max.    : 672.0   Max.    :1480.0   Max.    :1090.0
##
##  classe
##  A:5580
##  B:3797
##  C:3422
##  D:3216
##  E:3607
##
##
##  summary(testdataset)
##          X.1             X           user_name raw_timestamp_part_1
##  Min.    : 1.00   Min.    : 1.00    adelmo  :1   Min.    :1.322e+09

```

```

## 1st Qu.: 5.75    1st Qu.: 5.75    carlitos:3    1st Qu.:1.323e+09
## Median :10.50    Median :10.50    charles :1     Median :1.323e+09
## Mean   :10.50    Mean   :10.50    eurico  :4     Mean   :1.323e+09
## 3rd Qu.:15.25    3rd Qu.:15.25    jeremy   :8    3rd Qu.:1.323e+09
## Max.   :20.00    Max.   :20.00    pedro    :3     Max.   :1.323e+09
##
## raw_timestamp_part_2          cvtd_timestamp new_window num_window
## Min.   : 36553      30/11/2011 17:11:4    no:20       Min.   : 48.0
## 1st Qu.:268655      05/12/2011 11:24:3    no:20       1st Qu.:250.0
## Median :530706      30/11/2011 17:12:3    no:20       Median :384.5
## Mean   :512167      05/12/2011 14:23:2    no:20       Mean   :379.6
## 3rd Qu.:787738      28/11/2011 14:14:2    no:20       3rd Qu.:467.0
## Max.   :920315      02/12/2011 13:33:1    no:20       Max.   :859.0
##                               (Other)      :5
## roll_belt           pitch_belt        yaw_belt      total_accel_belt
## Min.   :-5.9200     Min.   :-41.600     Min.   :-93.70    Min.   : 2.00
## 1st Qu.: 0.9075     1st Qu.:  3.013     1st Qu.: -88.62   1st Qu.: 3.00
## Median : 1.1100     Median :  4.655     Median : -87.85   Median : 4.00
## Mean   : 31.3055    Mean   :  5.824     Mean   : -59.30   Mean   : 7.55
## 3rd Qu.: 32.5050    3rd Qu.:  6.135     3rd Qu.: -63.50   3rd Qu.: 8.00
## Max.   :129.0000    Max.   : 27.800     Max.   :162.00    Max.   :21.00
##
## gyros_belt_x      gyros_belt_y      gyros_belt_z      accel_belt_x
## Min.   :-0.500     Min.   :-0.050     Min.   :-0.4800   Min.   :-48.00
## 1st Qu.: -0.070    1st Qu.: -0.005    1st Qu.: -0.1375  1st Qu.: -19.00
## Median :  0.020     Median :  0.000     Median : -0.0250  Median : -13.00
## Mean   : -0.045    Mean   :  0.010     Mean   : -0.1005  Mean   : -13.50
## 3rd Qu.:  0.070     3rd Qu.:  0.020     3rd Qu.:  0.0000  3rd Qu.: -8.75
## Max.   :  0.240     Max.   :  0.110     Max.   :  0.0500  Max.   : 46.00
##
## accel_belt_y      accel_belt_z      magnet_belt_x    magnet_belt_y
## Min.   :-16.00     Min.   :-187.00    Min.   :-13.00    Min.   :566.0
## 1st Qu.:  2.00     1st Qu.: -24.00    1st Qu.:  5.50    1st Qu.:578.5
## Median :  4.50     Median :  27.00     Median : 33.50    Median :600.5
## Mean   : 18.35     Mean   : -17.60    Mean   : 35.15    Mean   :601.5
## 3rd Qu.: 25.50     3rd Qu.: 38.25     3rd Qu.: 46.25    3rd Qu.:631.2
## Max.   : 72.00     Max.   : 49.00     Max.   :169.00    Max.   :638.0
##
## magnet_belt_z      roll_arm        pitch_arm        yaw_arm
## Min.   :-426.0     Min.   :-137.00    Min.   :-63.800   Min.   :-167.00
## 1st Qu.: -398.5    1st Qu.:  0.00     1st Qu.: -9.188   1st Qu.: -60.15
## Median :-313.5     Median :  0.00     Median :  0.000    Median :  0.00
## Mean   :-346.9     Mean   : 16.42     Mean   : -3.950    Mean   : -2.80
## 3rd Qu.: -305.0    3rd Qu.: 71.53     3rd Qu.:  3.465    3rd Qu.: 25.50
## Max.   :-291.0     Max.   :152.00     Max.   : 55.000   Max.   : 178.00
##
## total_accel_arm   gyros_arm_x      gyros_arm_y      gyros_arm_z
## Min.   : 3.00      Min.   :-3.710     Min.   :-2.0900   Min.   :-0.6900
## 1st Qu.:20.25      1st Qu.: -0.645    1st Qu.: -0.6350  1st Qu.: -0.1800
## Median :29.50      Median :  0.020     Median : -0.0400  Median : -0.0250
## Mean   :26.40      Mean   :  0.077     Mean   : -0.1595  Mean   :  0.1205
## 3rd Qu.:33.25      3rd Qu.:  1.248    3rd Qu.:  0.2175  3rd Qu.:  0.5650
## Max.   :44.00      Max.   :  3.660     Max.   :  1.8500  Max.   :  1.1300
##

```

```

##   accel_arm_x      accel_arm_y      accel_arm_z      magnet_arm_x
## Min.    :-341.0    Min.    :-65.00    Min.    :-404.00    Min.    :-428.00
## 1st Qu.:-277.0    1st Qu.: 52.25    1st Qu.:-128.50    1st Qu.:-373.75
## Median : -194.5    Median :112.00    Median : -83.50    Median : -265.00
## Mean    : -134.6    Mean    :103.10    Mean    : -87.85    Mean    : -38.95
## 3rd Qu.:   5.5     3rd Qu.:168.25    3rd Qu.: -27.25    3rd Qu.: 250.50
## Max.    : 106.0     Max.    :245.00    Max.    :  93.00    Max.    : 750.00
##
##   magnet_arm_y      magnet_arm_z      roll_dumbbell    pitch_dumbbell
## Min.    :-307.0    Min.    :-499.0    Min.    :-111.118   Min.    :-54.97
## 1st Qu.: 205.2    1st Qu.: 403.0    1st Qu.:  7.494    1st Qu.:-51.89
## Median : 291.0     Median : 476.5    Median : 50.403    Median : -40.81
## Mean    : 239.4     Mean    : 369.8    Mean    : 33.760    Mean    : -19.47
## 3rd Qu.: 358.8    3rd Qu.: 517.0    3rd Qu.: 58.129    3rd Qu.: 16.12
## Max.    : 474.0     Max.    : 633.0    Max.    :123.984    Max.    : 96.87
##
##   yaw_dumbbell      total_accel_dumbbell gyros_dumbbell_x
## Min.    :-103.3200   Min.    : 1.0        Min.    :-1.0300
## 1st Qu.: -75.2809   1st Qu.: 7.0        1st Qu.: 0.1600
## Median : -8.2863     Median :15.5        Median : 0.3600
## Mean    : -0.9385    Mean    :17.2        Mean    : 0.2690
## 3rd Qu.: 55.8335    3rd Qu.:29.0        3rd Qu.: 0.4625
## Max.    : 132.2337   Max.    :31.0        Max.    : 1.0600
##
##   gyros_dumbbell_y  gyros_dumbbell_z  accel_dumbbell_x  accel_dumbbell_y
## Min.    :-1.1100     Min.    :-1.180    Min.    :-159.00    Min.    :-30.00
## 1st Qu.: -0.2100     1st Qu.:-0.485    1st Qu.:-140.25    1st Qu.: 5.75
## Median : 0.0150     Median :-0.280    Median : -19.00    Median : 71.50
## Mean    : 0.0605     Mean    :-0.266    Mean    : -47.60    Mean    : 70.55
## 3rd Qu.: 0.1450     3rd Qu.:-0.165    3rd Qu.: 15.75    3rd Qu.:151.25
## Max.    : 1.9100     Max.    : 1.100    Max.    : 185.00    Max.    :166.00
##
##   accel_dumbbell_z  magnet_dumbbell_x  magnet_dumbbell_y  magnet_dumbbell_z
## Min.    :-221.0     Min.    :-576.0    Min.    :-558.0    Min.    :-164.00
## 1st Qu.: -192.2     1st Qu.:-528.0    1st Qu.: 259.5    1st Qu.: -33.00
## Median : -3.0       Median :-508.5    Median : 316.0    Median : 49.50
## Mean    : -60.0      Mean    :-304.2    Mean    : 189.3    Mean    : 71.40
## 3rd Qu.: 76.5       3rd Qu.:-317.0    3rd Qu.: 348.2    3rd Qu.: 96.25
## Max.    : 100.0      Max.    : 523.0    Max.    : 403.0    Max.    : 368.00
##
##   roll_forearm      pitch_forearm      yaw_forearm
## Min.    :-176.00    Min.    :-63.500   Min.    :-168.000
## 1st Qu.: -40.25    1st Qu.:-11.457   1st Qu.: -93.375
## Median : 94.20      Median : 8.830    Median : -19.250
## Mean    : 38.66      Mean    : 7.099    Mean    : 2.195
## 3rd Qu.: 143.25    3rd Qu.: 28.500    3rd Qu.: 104.500
## Max.    : 176.00     Max.    : 59.300    Max.    : 159.000
##
##   total_accel_forearm gyros_forearm_x  gyros_forearm_y  gyros_forearm_z
## Min.    :21.00       Min.    :-1.0600   Min.    :-5.9700   Min.    :-1.2600
## 1st Qu.:24.00       1st Qu.:-0.5850   1st Qu.:-1.2875   1st Qu.:-0.0975
## Median :32.50       Median : 0.0200    Median : 0.0350    Median : 0.2300
## Mean    :32.05       Mean    :-0.0200   Mean    :-0.0415    Mean    : 0.2610
## 3rd Qu.:36.75       3rd Qu.: 0.2925   3rd Qu.: 2.0475   3rd Qu.: 0.7625

```

```

##  Max.    :47.00      Max.    : 1.3800  Max.    : 4.2600  Max.    : 1.8000
##
##  accel_forearm_x  accel_forearm_y  accel_forearm_z  magnet_forearm_x
##  Min.   :-212.0    Min.   :-331.0    Min.   :-282.0    Min.   :-714.0
##  1st Qu.:-114.8    1st Qu.: 8.5     1st Qu.:-199.0    1st Qu.:-427.2
##  Median : 86.0     Median :138.0     Median :-148.5    Median :-189.5
##  Mean   : 38.8     Mean   :125.3     Mean   :-93.7     Mean   :-159.2
##  3rd Qu.:166.2     3rd Qu.:268.0     3rd Qu.:-31.0    3rd Qu.: 41.5
##  Max.   :232.0     Max.   :406.0     Max.   :179.0     Max.   :532.0
##
##  magnet_forearm_y  magnet_forearm_z  problem_id
##  Min.   :-787.0    Min.   :-32.0     Min.   : 1.00
##  1st Qu.:-328.8    1st Qu.:275.2     1st Qu.: 5.75
##  Median : 487.0    Median :491.5     Median :10.50
##  Mean   :191.8     Mean   :460.2     Mean   :10.50
##  3rd Qu.:720.8     3rd Qu.:661.5     3rd Qu.:15.25
##  Max.   :800.0     Max.   :884.0     Max.   :20.00
##

```

#Structure of data

```
str(traindataset)
```

```

## 'data.frame': 19622 obs. of 61 variables:
## $ X.1          : int 1 2 3 4 5 6 7 8 9 10 ...
## $ X            : int 1 2 3 4 5 6 7 8 9 10 ...
## $ user_name    : Factor w/ 6 levels "adelmo","carlitos",...: 2 2 2 2 2 2 2 2 2 2 ...
## $ 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 : Factor w/ 20 levels "02/12/2011 13:32",...: 9 9 9 9 9 9 9 9 9 9 ...
## $ new_window    : Factor w/ 2 levels "no","yes": 1 1 1 1 1 1 1 1 1 1 ...
## $ 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 ...
## $ gyros_belt_x : num 0 0.02 0 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 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 ...
## $ gyros_arm_x  : num 0 0.02 0.02 0.02 0 0.02 0.02 0.02 0.02 ...
## $ gyros_arm_y  : num 0 -0.02 -0.02 -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 -0.02 -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 ...
## $ 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 ...
## $ total_accel_dumbbell: int 37 37 37 37 37 37 37 37 37 37 ...
## $ gyros_dumbbell_x   : num 0 0 0 0 0 0 0 0 0 0 ...
## $ gyros_dumbbell_y   : num -0.02 -0.02 -0.02 -0.02 -0.02 -0.02 -0.02 -0.02 -0.02 -0.02 ...
## $ gyros_dumbbell_z   : num 0 0 0 -0.02 0 0 0 0 0 0 ...
## $ accel_dumbbell_x   : int -234 -233 -232 -232 -233 -234 -232 -234 -232 -235 ...
## $ accel_dumbbell_y   : int 47 47 46 48 48 48 47 46 47 48 ...
## $ accel_dumbbell_z   : int -271 -269 -270 -269 -270 -269 -270 -272 -269 -270 ...
## $ magnet_dumbbell_x   : int -559 -555 -561 -552 -554 -558 -551 -555 -549 -558 ...
## $ magnet_dumbbell_y   : int 293 296 298 303 292 294 295 300 292 291 ...
## $ magnet_dumbbell_z   : num -65 -64 -63 -60 -68 -66 -70 -74 -65 -69 ...
## $ roll_forearm        : num 28.4 28.3 28.3 28.1 28 27.9 27.9 27.8 27.7 27.7 ...
## $ pitch_forearm       : num -63.9 -63.9 -63.9 -63.9 -63.9 -63.9 -63.9 -63.8 -63.8 -63.8 ...
## $ yaw_forearm         : num -153 -153 -152 -152 -152 -152 -152 -152 -152 -152 ...
## $ total_accel_forearm: int 36 36 36 36 36 36 36 36 36 36 ...
## $ gyros_forearm_x     : num 0.03 0.02 0.03 0.02 0.02 0.02 0.02 0.03 0.02 0.02 ...
## $ gyros_forearm_y     : num 0 0 -0.02 -0.02 0 -0.02 0 -0.02 0 0 ...
## $ gyros_forearm_z     : num -0.02 -0.02 0 0 -0.02 -0.03 -0.02 0 -0.02 -0.02 ...
## $ accel_forearm_x     : int 192 192 196 189 189 193 195 193 193 190 ...
## $ accel_forearm_y     : int 203 203 204 206 206 203 205 205 204 205 ...
## $ accel_forearm_z     : int -215 -216 -213 -214 -214 -215 -215 -213 -214 -215 ...
## $ magnet_forearm_x    : int -17 -18 -18 -16 -17 -9 -18 -9 -16 -22 ...
## $ magnet_forearm_y    : num 654 661 658 658 655 660 659 660 653 656 ...
## $ magnet_forearm_z    : num 476 473 469 469 473 478 470 474 476 473 ...
## $ classe              : Factor w/ 5 levels "A","B","C","D",...: 1 1 1 1 1 1 1 1 1 1 ...
str(testdataset)

## 'data.frame': 20 obs. of 61 variables:
## $ X.1                  : int 1 2 3 4 5 6 7 8 9 10 ...
## $ X                     : int 1 2 3 4 5 6 7 8 9 10 ...
## $ user_name             : Factor w/ 6 levels "adelmo","carlitos",...: 6 5 5 1 4 5 5 5 2 3 ...
## $ raw_timestamp_part_1: int 1323095002 1322673067 1322673075 1322832789 1322489635 1322673149 1322...
## $ raw_timestamp_part_2: int 868349 778725 342967 560311 814776 510661 766645 54671 916313 384285 ...
## $ cvtd_timestamp        : Factor w/ 11 levels "02/12/2011 13:33",...: 5 10 10 1 6 11 11 10 3 2 ...
## $ new_window            : Factor w/ 1 level "no": 1 1 1 1 1 1 1 1 1 1 ...
## $ num_window            : int 74 431 439 194 235 504 485 440 323 664 ...
## $ roll_belt              : num 123 1.02 0.87 125 1.35 -5.92 1.2 0.43 0.93 114 ...
## $ pitch_belt             : num 27 4.87 1.82 -41.6 3.33 1.59 4.44 4.15 6.72 22.4 ...
## $ yaw_belt               : num -4.75 -88.9 -88.5 162 -88.6 -87.7 -87.3 -88.5 -93.7 -13.1 ...
## $ total_accel_belt       : int 20 4 5 17 3 4 4 4 4 18 ...
## $ gyros_belt_x           : num -0.5 -0.06 0.05 0.11 0.03 0.1 -0.06 -0.18 0.1 0.14 ...
## $ gyros_belt_y           : num -0.02 -0.02 0.02 0.11 0.02 0.05 0 -0.02 0 0.11 ...
## $ gyros_belt_z           : num -0.46 -0.07 0.03 -0.16 0 -0.13 0 -0.03 -0.02 -0.16 ...
## $ accel_belt_x           : int -38 -13 1 46 -8 -11 -14 -10 -15 -25 ...
## $ accel_belt_y           : int 69 11 -1 45 4 -16 2 -2 1 63 ...
## $ accel_belt_z           : int -179 39 49 -156 27 38 35 42 32 -158 ...
## $ magnet_belt_x          : int -13 43 29 169 33 31 50 39 -6 10 ...
## $ magnet_belt_y          : int 581 636 631 608 566 638 622 635 600 601 ...
## $ magnet_belt_z          : int -382 -309 -312 -304 -418 -291 -315 -305 -302 -330 ...
## $ roll_arm                : num 40.7 0 0 -109 76.1 0 0 0 -137 -82.4 ...

```

```

## $ pitch_arm          : num -27.8 0 0 55 2.76 0 0 0 11.2 -63.8 ...
## $ yaw_arm            : num 178 0 0 -142 102 0 0 0 -167 -75.3 ...
## $ total_accel_arm    : int 10 38 44 25 29 14 15 22 34 32 ...
## $ gyros_arm_x        : num -1.65 -1.17 2.1 0.22 -1.96 0.02 2.36 -3.71 0.03 0.26 ...
## $ gyros_arm_y        : num 0.48 0.85 -1.36 -0.51 0.79 0.05 -1.01 1.85 -0.02 -0.5 ...
## $ gyros_arm_z        : num -0.18 -0.43 1.13 0.92 -0.54 -0.07 0.89 -0.69 -0.02 0.79 ...
## $ accel_arm_x         : int 16 -290 -341 -238 -197 -26 99 -98 -287 -301 ...
## $ accel_arm_y         : int 38 215 245 -57 200 130 79 175 111 -42 ...
## $ accel_arm_z         : int 93 -90 -87 6 -30 -19 -67 -78 -122 -80 ...
## $ magnet_arm_x        : int -326 -325 -264 -173 -170 396 702 535 -367 -420 ...
## $ magnet_arm_y        : int 385 447 474 257 275 176 15 215 335 294 ...
## $ magnet_arm_z        : int 481 434 413 633 617 516 217 385 520 493 ...
## $ roll_dumbbell       : num -17.7 54.5 57.1 43.1 -101.4 ...
## $ pitch_dumbbell      : num 25 -53.7 -51.4 -30 -53.4 ...
## $ yaw_dumbbell        : num 126.2 -75.5 -75.2 -103.3 -14.2 ...
## $ total_accel_dumbbell: int 9 31 29 18 4 29 29 29 3 2 ...
## $ gyros_dumbbell_x    : num 0.64 0.34 0.39 0.1 0.29 -0.59 0.34 0.37 0.03 0.42 ...
## $ gyros_dumbbell_y    : num 0.06 0.05 0.14 -0.02 -0.47 0.8 0.16 0.14 -0.21 0.51 ...
## $ gyros_dumbbell_z    : num -0.61 -0.71 -0.34 0.05 -0.46 1.1 -0.23 -0.39 -0.21 -0.03 ...
## $ accel_dumbbell_x   : int 21 -153 -141 -51 -18 -138 -145 -140 0 -7 ...
## $ accel_dumbbell_y   : int -15 155 155 72 -30 166 150 159 25 -20 ...
## $ accel_dumbbell_z   : int 81 -205 -196 -148 -5 -186 -190 -191 9 7 ...
## $ magnet_dumbbell_x   : int 523 -502 -506 -576 -424 -543 -484 -515 -519 -531 ...
## $ magnet_dumbbell_y   : int -528 388 349 238 252 262 354 350 348 321 ...
## $ magnet_dumbbell_z   : int -56 -36 41 53 312 96 97 53 -32 -164 ...
## $ roll_forearm         : num 141 109 131 0 -176 150 155 -161 15.5 13.2 ...
## $ pitch_forearm        : num 49.3 -17.6 -32.6 0 -2.16 1.46 34.5 43.6 -63.5 19.4 ...
## $ yaw_forearm          : num 156 106 93 0 -47.9 89.7 152 -89.5 -139 -105 ...
## $ total_accel_forearm : int 33 39 34 43 24 43 32 47 36 24 ...
## $ gyros_forearm_x      : num 0.74 1.12 0.18 1.38 -0.75 -0.88 -0.53 0.63 0.03 0.02 ...
## $ gyros_forearm_y      : num -3.34 -2.78 -0.79 0.69 3.1 4.26 1.8 -0.74 0.02 0.13 ...
## $ gyros_forearm_z      : num -0.59 -0.18 0.28 1.8 0.8 1.35 0.75 0.49 -0.02 -0.07 ...
## $ accel_forearm_x       : int -110 212 154 -92 131 230 -192 -151 195 -212 ...
## $ accel_forearm_y       : int 267 297 271 406 -93 322 170 -331 204 98 ...
## $ accel_forearm_z       : int -149 -118 -129 -39 172 -144 -175 -282 -217 -7 ...
## $ magnet_forearm_x      : int -714 -237 -51 -233 375 -300 -678 -109 0 -403 ...
## $ magnet_forearm_y      : int 419 791 698 783 -787 800 284 -619 652 723 ...
## $ magnet_forearm_z      : int 617 873 783 521 91 884 585 -32 469 512 ...
## $ problem_id           : int 1 2 3 4 5 6 7 8 9 10 ...
# Variables "X.1", "X", "user_name", "raw_timestamp_part_1", "raw_timestamp_part_2" "cvt_d_timestamp", ...
traindataset <- traindataset[,-c(1:8)]
testdata <- testdataset[,-c(1:8)]
# saved to working dir
write.csv(traindataset, "traindataset.csv")
write.csv(testdata, "testdataset.csv")
# Review final datasets
head(traindataset)

## roll_belt pitch_belt yaw_belt total_accel_belt gyros_belt_x gyros_belt_y
## 1     1.41      8.07   -94.4          3     0.00     0.00
## 2     1.41      8.07   -94.4          3     0.02     0.00
## 3     1.42      8.07   -94.4          3     0.00     0.00
## 4     1.48      8.05   -94.4          3     0.02     0.00
## 5     1.48      8.07   -94.4          3     0.02     0.02

```

```

## 6      1.45      8.06     -94.4          3      0.02      0.00
##   gyros_belt_z accel_belt_x accel_belt_y accel_belt_z magnet_belt_x
## 1      -0.02      -21         4       22      -3
## 2      -0.02      -22         4       22      -7
## 3      -0.02      -20         5       23      -2
## 4      -0.03      -22         3       21      -6
## 5      -0.02      -21         2       24      -6
## 6      -0.02      -21         4       21      0
##   magnet_belt_y magnet_belt_z roll_arm pitch_arm yaw_arm total_accel_arm
## 1      599      -313     -128     22.5    -161      34
## 2      608      -311     -128     22.5    -161      34
## 3      600      -305     -128     22.5    -161      34
## 4      604      -310     -128     22.1    -161      34
## 5      600      -302     -128     22.1    -161      34
## 6      603      -312     -128     22.0    -161      34
##   gyros_arm_x gyros_arm_y gyros_arm_z accel_arm_x accel_arm_y accel_arm_z
## 1      0.00      0.00     -0.02     -288      109     -123
## 2      0.02     -0.02     -0.02     -290      110     -125
## 3      0.02     -0.02     -0.02     -289      110     -126
## 4      0.02     -0.03      0.02     -289      111     -123
## 5      0.00     -0.03      0.00     -289      111     -123
## 6      0.02     -0.03      0.00     -289      111     -122
##   magnet_arm_x magnet_arm_y magnet_arm_z roll_dumbbell pitch_dumbbell
## 1     -368      337      516  13.05217    -70.49400
## 2     -369      337      513  13.13074    -70.63751
## 3     -368      344      513  12.85075    -70.27812
## 4     -372      344      512  13.43120    -70.39379
## 5     -374      337      506  13.37872    -70.42856
## 6     -369      342      513  13.38246    -70.81759
##   yaw_dumbbell total_accel_dumbbell gyros_dumbbell_x gyros_dumbbell_y
## 1     -84.87394           37          0     -0.02
## 2     -84.71065           37          0     -0.02
## 3     -85.14078           37          0     -0.02
## 4     -84.87363           37          0     -0.02
## 5     -84.85306           37          0     -0.02
## 6     -84.46500           37          0     -0.02
##   gyros_dumbbell_z accel_dumbbell_x accel_dumbbell_y accel_dumbbell_z
## 1      0.00      -234        47     -271
## 2      0.00      -233        47     -269
## 3      0.00      -232        46     -270
## 4     -0.02      -232        48     -269
## 5      0.00      -233        48     -270
## 6      0.00      -234        48     -269
##   magnet_dumbbell_x magnet_dumbbell_y magnet_dumbbell_z roll_forearm
## 1     -559      293       -65      28.4
## 2     -555      296       -64      28.3
## 3     -561      298       -63      28.3
## 4     -552      303       -60      28.1
## 5     -554      292       -68      28.0
## 6     -558      294       -66      27.9
##   pitch_forearm yaw_forearm total_accel_forearm gyros_forearm_x
## 1     -63.9      -153        36      0.03
## 2     -63.9      -153        36      0.02
## 3     -63.9      -152        36      0.03

```

```

## 4      -63.9      -152          36       0.02
## 5      -63.9      -152          36       0.02
## 6      -63.9      -152          36       0.02
##   gyros_forearm_y gyros_forearm_z accel_forearm_x accel_forearm_y
## 1        0.00      -0.02       192       203
## 2        0.00      -0.02       192       203
## 3      -0.02       0.00       196       204
## 4      -0.02       0.00       189       206
## 5        0.00      -0.02       189       206
## 6      -0.02      -0.03       193       203
##   accel_forearm_z magnet_forearm_x magnet_forearm_y magnet_forearm_z
## 1      -215       -17       654       476
## 2      -216       -18       661       473
## 3      -213       -18       658       469
## 4      -214       -16       658       469
## 5      -214       -17       655       473
## 6      -215        -9       660       478
##   classe
## 1     A
## 2     A
## 3     A
## 4     A
## 5     A
## 6     A
head(testdataset)

##   roll_belt pitch_belt yaw_belt total_accel_belt gyros_belt_x gyros_belt_y
## 1    123.00     27.00    -4.75          20      -0.50      -0.02
## 2     1.02      4.87   -88.90           4      -0.06      -0.02
## 3     0.87      1.82   -88.50           5       0.05       0.02
## 4    125.00    -41.60   162.00          17       0.11       0.11
## 5     1.35      3.33   -88.60           3       0.03       0.02
## 6    -5.92      1.59   -87.70           4       0.10       0.05
##   gyros_belt_z accel_belt_x accel_belt_y accel_belt_z magnet_belt_x
## 1      -0.46      -38       69      -179      -13
## 2      -0.07      -13       11       39       43
## 3      0.03       1       -1       49       29
## 4      -0.16       46       45      -156      169
## 5      0.00       -8       4       27       33
## 6      -0.13      -11      -16       38       31
##   magnet_belt_y magnet_belt_z roll_arm pitch_arm yaw_arm total_accel_arm
## 1      581      -382     40.7     -27.80      178       10
## 2      636      -309      0.0      0.00       0       38
## 3      631      -312      0.0      0.00       0       44
## 4      608      -304    -109.0     55.00     -142       25
## 5      566      -418     76.1      2.76      102       29
## 6      638      -291      0.0      0.00       0       14
##   gyros_arm_x gyros_arm_y gyros_arm_z accel_arm_x accel_arm_y accel_arm_z
## 1     -1.65      0.48     -0.18       16       38       93
## 2     -1.17      0.85     -0.43      -290      215      -90
## 3      2.10     -1.36      1.13      -341      245      -87
## 4      0.22     -0.51      0.92      -238      -57        6
## 5     -1.96      0.79     -0.54      -197      200      -30
## 6      0.02      0.05     -0.07      -26      130      -19

```

```

## magnet_arm_x magnet_arm_y magnet_arm_z roll_dumbbell pitch_dumbbell
## 1      -326        385       481    -17.73748     24.96085
## 2      -325        447       434     54.47761    -53.69758
## 3      -264        474       413     57.07031    -51.37303
## 4      -173        257       633     43.10927    -30.04885
## 5      -170        275       617    -101.38396    -53.43952
## 6       396        176       516     62.18750    -50.55595
## yaw_dumbbell total_accel_dumbbell gyros_dumbbell_x gyros_dumbbell_y
## 1      126.23596          9       0.64      0.06
## 2     -75.51480         31       0.34      0.05
## 3     -75.20287         29       0.39      0.14
## 4    -103.32003         18       0.10     -0.02
## 5     -14.19542          4       0.29     -0.47
## 6    -71.12063         29      -0.59      0.80
## gyros_dumbbell_z accel_dumbbell_x accel_dumbbell_y accel_dumbbell_z
## 1      -0.61         21      -15       81
## 2      -0.71        -153      155     -205
## 3      -0.34        -141      155     -196
## 4       0.05        -51       72     -148
## 5      -0.46        -18      -30       -5
## 6       1.10        -138      166     -186
## magnet_dumbbell_x magnet_dumbbell_y magnet_dumbbell_z roll_forearm
## 1       523        -528      -56      141
## 2      -502         388      -36      109
## 3      -506         349       41      131
## 4      -576         238       53       0
## 5      -424         252      312     -176
## 6      -543         262       96      150
## pitch_forearm yaw_forearm total_accel_forearm gyros_forearm_x
## 1      49.30        156.0      33      0.74
## 2     -17.60        106.0      39      1.12
## 3     -32.60        93.0       34      0.18
## 4       0.00         0.0       43      1.38
## 5     -2.16        -47.9      24     -0.75
## 6      1.46         89.7      43     -0.88
## gyros_forearm_y gyros_forearm_z accel_forearm_x accel_forearm_y
## 1      -3.34        -0.59     -110      267
## 2      -2.78        -0.18      212      297
## 3      -0.79         0.28      154      271
## 4       0.69         1.80      -92      406
## 5       3.10         0.80      131     -93
## 6      4.26         1.35      230      322
## accel_forearm_z magnet_forearm_x magnet_forearm_y magnet_forearm_z
## 1      -149        -714       419      617
## 2      -118        -237       791      873
## 3      -129        -51       698      783
## 4       -39        -233       783      521
## 5       172         375      -787       91
## 6      -144        -300       800      884
## problem_id
## 1       1
## 2       2
## 3       3
## 4       4

```

```

## 5      5
## 6      6
dim(traindataset)

## [1] 19622    53
dim(testdataset)

## [1] 20 53

```

3. Partitioning the training data set to allow cross-validation

traindataset: 53 variables and 19622 obs

testdataset: 53 variables and 20 obs.

```

#In order to perform cross-validation, the training data set is partitionned into 2 sets: subTraining (75%
subsamples <- createDataPartition(y=traindataset$classe, p=0.75, list=FALSE)
subTraining <- traindataset[subsamples, ]
subTesting <- traindataset[-subsamples, ]
dim(subTraining)

## [1] 14718    53
dim(subTesting)

## [1] 4904    53
head(subTraining)

##   roll_belt pitch_belt yaw_belt total_accel_belt gyros_belt_x gyros_belt_y
## 2     1.41     8.07   -94.4          3       0.02      0.00
## 3     1.42     8.07   -94.4          3       0.00      0.00
## 4     1.48     8.05   -94.4          3       0.02      0.00
## 5     1.48     8.07   -94.4          3       0.02      0.02
## 6     1.45     8.06   -94.4          3       0.02      0.00
## 7     1.42     8.09   -94.4          3       0.02      0.00
##   gyros_belt_z accel_belt_x accel_belt_y accel_belt_z magnet_belt_x
## 2     -0.02      -22          4        22       -7
## 3     -0.02      -20          5        23       -2
## 4     -0.03      -22          3        21       -6
## 5     -0.02      -21          2        24       -6
## 6     -0.02      -21          4        21        0
## 7     -0.02      -22          3        21       -4
##   magnet_belt_y magnet_belt_z roll_arm pitch_arm yaw_arm total_accel_arm
## 2       608      -311      -128      22.5     -161      34
## 3       600      -305      -128      22.5     -161      34
## 4       604      -310      -128      22.1     -161      34
## 5       600      -302      -128      22.1     -161      34
## 6       603      -312      -128      22.0     -161      34
## 7       599      -311      -128      21.9     -161      34
##   gyros_arm_x gyros_arm_y gyros_arm_z accel_arm_x accel_arm_y accel_arm_z
## 2       0.02     -0.02     -0.02      -290       110     -125

```

```

## 3      0.02     -0.02     -0.02      -289       110      -126
## 4      0.02     -0.03      0.02      -289       111      -123
## 5      0.00     -0.03      0.00      -289       111      -123
## 6      0.02     -0.03      0.00      -289       111      -122
## 7      0.00     -0.03      0.00      -289       111      -125
##   magnet_arm_x magnet_arm_y magnet_arm_z roll_dumbbell pitch_dumbbell
## 2      -369      337      513    13.13074     -70.63751
## 3      -368      344      513    12.85075     -70.27812
## 4      -372      344      512    13.43120     -70.39379
## 5      -374      337      506    13.37872     -70.42856
## 6      -369      342      513    13.38246     -70.81759
## 7      -373      336      509    13.12695     -70.24757
##   yaw_dumbbell total_accel_dumbbell gyros_dumbbell_x gyros_dumbbell_y
## 2     -84.71065          37          0      -0.02
## 3     -85.14078          37          0      -0.02
## 4     -84.87363          37          0      -0.02
## 5     -84.85306          37          0      -0.02
## 6     -84.46500          37          0      -0.02
## 7     -85.09961          37          0      -0.02
##   gyros_dumbbell_z accel_dumbbell_x accel_dumbbell_y accel_dumbbell_z
## 2      0.00      -233        47      -269
## 3      0.00      -232        46      -270
## 4     -0.02      -232        48      -269
## 5      0.00      -233        48      -270
## 6      0.00      -234        48      -269
## 7      0.00      -232        47      -270
##   magnet_dumbbell_x magnet_dumbbell_y magnet_dumbbell_z roll_forearm
## 2      -555      296       -64      28.3
## 3      -561      298       -63      28.3
## 4      -552      303       -60      28.1
## 5      -554      292       -68      28.0
## 6      -558      294       -66      27.9
## 7      -551      295       -70      27.9
##   pitch_forearm yaw_forearm total_accel_forearm gyros_forearm_x
## 2     -63.9      -153        36      0.02
## 3     -63.9      -152        36      0.03
## 4     -63.9      -152        36      0.02
## 5     -63.9      -152        36      0.02
## 6     -63.9      -152        36      0.02
## 7     -63.9      -152        36      0.02
##   gyros_forearm_y gyros_forearm_z accel_forearm_x accel_forearm_y
## 2      0.00      -0.02      192      203
## 3     -0.02       0.00      196      204
## 4     -0.02       0.00      189      206
## 5      0.00      -0.02      189      206
## 6     -0.02      -0.03      193      203
## 7      0.00      -0.02      195      205
##   accel_forearm_z magnet_forearm_x magnet_forearm_y magnet_forearm_z
## 2     -216       -18       661      473
## 3     -213       -18       658      469
## 4     -214       -16       658      469
## 5     -214       -17       655      473
## 6     -215        -9       660      478
## 7     -215       -18       659      470

```

```

## classe
## 2      A
## 3      A
## 4      A
## 5      A
## 6      A
## 7      A

head(subTesting)

##   roll_belt pitch_belt yaw_belt total_accel_belt gyros_belt_x
## 1      1.41      8.07    -94.4          3      0.00
## 21     1.60      8.10    -94.4          3      0.02
## 22     1.57      8.09    -94.4          3      0.02
## 23     1.56      8.10    -94.3          3      0.02
## 25     1.53      8.11    -94.4          3      0.03
## 26     1.55      8.09    -94.4          3      0.02
##   gyros_belt_y gyros_belt_z accel_belt_x accel_belt_y accel_belt_z
## 1      0.00     -0.02      -21          4      22
## 21     0.00     -0.02      -20          1      20
## 22     0.02     -0.02      -21          3      21
## 23     0.00     -0.02      -21          4      21
## 25     0.00      0.00      -19          4      21
## 26     0.00      0.00      -21          3      22
##   magnet_belt_x magnet_belt_y magnet_belt_z roll_arm pitch_arm yaw_arm
## 1      -3        599     -313      -128     22.5    -161
## 21     -10       607     -304      -129     20.9    -161
## 22     -2        604     -313      -129     20.8    -161
## 23     -4        606     -311      -129     20.7    -161
## 25     -8        605     -319      -129     20.7    -161
## 26     -10       601     -312      -129     20.7    -161
##   total_accel_arm gyros_arm_x gyros_arm_y gyros_arm_z accel_arm_x
## 1      34        0.00     0.00     -0.02     -288
## 21     34        0.03     -0.02    -0.02     -288
## 22     34        0.03     -0.02    -0.02     -289
## 23     34        0.02     -0.02    -0.02     -290
## 25     34       -0.02     -0.02     0.00     -289
## 26     34       -0.02     -0.02    -0.02     -290
##   accel_arm_y accel_arm_z magnet_arm_x magnet_arm_y magnet_arm_z
## 1      109      -123     -368      337      516
## 21     111      -124     -375      337      513
## 22     111      -123     -372      338      510
## 23     110      -123     -373      333      509
## 25     109      -123     -370      340      512
## 26     108      -123     -366      346      511
##   roll_dumbbell pitch_dumbbell yaw_dumbbell total_accel_dumbbell
## 1      13.05217   -70.49400  -84.87394      37
## 21     13.38246   -70.81759  -84.46500      37
## 22     13.37872   -70.42856  -84.85306      37
## 23     13.35451   -70.63995  -84.64919      37
## 25     13.05217   -70.49400  -84.87394      37
## 26     12.80060   -70.31305  -85.11886      37
##   gyros_dumbbell_x gyros_dumbbell_y gyros_dumbbell_z accel_dumbbell_x
## 1      0          -0.02      0.00     -234
## 21     0          -0.02      0.00     -234

```

```

## 22          0        -0.02        0.00      -233
## 23          0        -0.02        0.00      -234
## 25          0        -0.02        0.00      -234
## 26          0        -0.02       -0.02      -233
##   accel_dumbbell_y accel_dumbbell_z magnet_dumbbell_x magnet_dumbbell_y
## 1           47        -271       -559       293
## 21          48        -269       -554       299
## 22          48        -270       -554       301
## 23          48        -270       -557       294
## 25          47        -271       -555       290
## 26          46        -271       -563       294
##   magnet_dumbbell_z roll_forearm pitch_forearm yaw_forearm
## 1           -65      28.4      -63.9      -153
## 21          -72      26.9      -63.9      -151
## 22          -65      27.0      -63.9      -151
## 23          -69      26.9      -63.8      -151
## 25          -68      27.1      -63.7      -151
## 26          -72      27.0      -63.7      -151
##   total_accel_forearm gyros_forearm_x gyros_forearm_y gyros_forearm_z
## 1            36       0.03       0.00      -0.02
## 21           36       0.03      -0.03      -0.02
## 22           36       0.02      -0.03      -0.02
## 23           36       0.02      -0.02      -0.02
## 25           36       0.05      -0.03       0.00
## 26           36       0.03       0.00       0.00
##   accel_forearm_x accel_forearm_y accel_forearm_z magnet_forearm_x
## 1            192      203      -215      -17
## 21           194      208      -214      -11
## 22           191      206      -213      -17
## 23           194      206      -214      -10
## 25           191      202      -214      -14
## 26           190      203      -216      -16
##   magnet_forearm_y magnet_forearm_z classe
## 1            654      476       A
## 21           654      469       A
## 22           654      478       A
## 23           653      467       A
## 25           667      470       A
## 26           658      462       A

```

4a. First Prediction model with Decision Tree

```

# Using rpart: Decision Tree
decisiontreemodel <- rpart(classe ~ ., data=subTraining, method="class")
decisiontreemodel_summary = summary(decisiontreemodel)

## Call:
## rpart(formula = classe ~ ., data = subTraining, method = "class")
## n= 14718
##
##          CP nsplit rel error     xerror      xstd
## 1  0.11535175      0 1.0000000 1.0000000 0.005195739

```

```

## 2 0.05987531      1 0.8846482 0.8858825 0.005548315
## 3 0.03446312      4 0.7050223 0.7814488 0.005718364
## 4 0.02990601      5 0.6705592 0.6623944 0.005751173
## 5 0.02212095      6 0.6406532 0.6061901 0.005708272
## 6 0.02050698      11 0.5155226 0.5525491 0.005631592
## 7 0.01955758      12 0.4950157 0.4999525 0.005521102
## 8 0.01898794      13 0.4754581 0.4693819 0.005440000
## 9 0.01433590      15 0.4374822 0.4437482 0.005361931
## 10 0.01101301     16 0.4231463 0.4240008 0.005295259
## 11 0.01063325     17 0.4121333 0.3895376 0.005164571
## 12 0.01044337     21 0.3625748 0.3789044 0.005120396
## 13 0.01000000     22 0.3521314 0.3724485 0.005092652
##
## Variable importance
##          roll_belt        accel_belt_z        pitch_belt
##          12                      7                      6
##          pitch_forearm       roll_forearm       magnet_dumbbell_y
##          6                      5                      4
##          accel_dumbbell_y   total_accel_dumbbell   total_accel_belt
##          4                      4                      4
##          yaw_belt           magnet_belt_z        accel_forearm_x
##          4                      4                      3
##          accel_belt_y        magnet_belt_x        roll_dumbbell
##          3                      3                      3
##          magnet_dumbbell_z   accel_belt_x        accel_dumbbell_x
##          3                      3                      2
##          magnet_forearm_z    magnet_forearm_y   accel_dumbbell_z
##          2                      2                      2
##          magnet_forearm_x    yaw_forearm         magnet_belt_y
##          2                      2                      1
##          accel_forearm_y    accel_forearm_z    gyros_belt_z
##          1                      1                      1
##          yaw_dumbbell        yaw_arm            magnet_arm_y
##          1                      1                      1
##          accel_arm_x         pitch_arm
##          1                      1
##
## Node number 1: 14718 observations, complexity param=0.1153518
## predicted class=A expected loss=0.7156543 P(node) =1
## class counts: 4185 2848 2567 2412 2706
## probabilities: 0.284 0.194 0.174 0.164 0.184
## left son=2 (13483 obs) right son=3 (1235 obs)
## Primary splits:
##          roll_belt < 130.5      to the left, improve=1110.8160, (0 missing)
##          pitch_forearm < -34.35   to the left, improve= 801.1791, (0 missing)
##          accel_belt_z < -187.5   to the right, improve= 679.0521, (0 missing)
##          magnet_belt_y < 555.5    to the right, improve= 638.1469, (0 missing)
##          total_accel_belt < 20.5   to the left, improve= 567.5270, (0 missing)
## Surrogate splits:
##          accel_belt_z < -187.5   to the right, agree=0.967, adj=0.602, (0 split)
##          total_accel_belt < 20.5   to the left, agree=0.960, adj=0.518, (0 split)
##          magnet_belt_z < -451.5   to the right, agree=0.935, adj=0.219, (0 split)
##          magnet_belt_y < 552.5    to the right, agree=0.934, adj=0.215, (0 split)
##          accel_belt_x < 55.5     to the left, agree=0.923, adj=0.082, (0 split)

```

```

## 
## Node number 2: 13483 observations, complexity param=0.05987531
##   predicted class=A expected loss=0.6903508 P(node) =0.9160891
##   class counts: 4175 2848 2567 2412 1481
##   probabilities: 0.310 0.211 0.190 0.179 0.110
##   left son=4 (1163 obs) right son=5 (12320 obs)
## Primary splits:
##   pitch_forearm < -34.35 to the left, improve=757.7394, (0 missing)
##   roll_forearm < 123.5 to the left, improve=455.0585, (0 missing)
##   magnet_dumbbell_y < 439.5 to the left, improve=427.6583, (0 missing)
##   magnet_arm_x < 70.5 to the left, improve=425.3833, (0 missing)
##   accel_arm_x < -270.5 to the left, improve=413.8988, (0 missing)
## Surrogate splits:
##   accel_forearm_x < 220.5 to the right, agree=0.934, adj=0.238, (0 split)
##   accel_dumbbell_x < -199.5 to the left, agree=0.932, adj=0.208, (0 split)
##   total_accel_dumbbell < 36.5 to the right, agree=0.931, adj=0.206, (0 split)
##   yaw_arm < -160.5 to the left, agree=0.926, adj=0.137, (0 split)
##   accel_dumbbell_z < -220.5 to the left, agree=0.925, adj=0.136, (0 split)
##
## Node number 3: 1235 observations
##   predicted class=E expected loss=0.008097166 P(node) =0.08391086
##   class counts: 10 0 0 0 1225
##   probabilities: 0.008 0.000 0.000 0.000 0.992
##
## Node number 4: 1163 observations
##   predicted class=A expected loss=0.003439381 P(node) =0.07901889
##   class counts: 1159 4 0 0 0
##   probabilities: 0.997 0.003 0.000 0.000 0.000
##
## Node number 5: 12320 observations, complexity param=0.05987531
##   predicted class=A expected loss=0.7551948 P(node) =0.8370703
##   class counts: 3016 2844 2567 2412 1481
##   probabilities: 0.245 0.231 0.208 0.196 0.120
##   left son=10 (10462 obs) right son=11 (1858 obs)
## Primary splits:
##   magnet_dumbbell_y < 439.5 to the left, improve=346.2935, (0 missing)
##   yaw_belt < 169.5 to the right, improve=344.3402, (0 missing)
##   roll_forearm < 126.5 to the left, improve=332.6486, (0 missing)
##   roll_dumbbell < 63.49251 to the left, improve=297.3350, (0 missing)
##   magnet_dumbbell_x < -446.5 to the left, improve=275.8782, (0 missing)
## Surrogate splits:
##   roll_dumbbell < 81.7374 to the left, agree=0.900, adj=0.339, (0 split)
##   accel_dumbbell_y < 195.5 to the left, agree=0.876, adj=0.179, (0 split)
##   total_accel_dumbbell < 31.5 to the left, agree=0.857, adj=0.054, (0 split)
##   gyros_dumbbell_y < 1.21 to the left, agree=0.856, adj=0.046, (0 split)
##   accel_forearm_x < -401.5 to the right, agree=0.855, adj=0.036, (0 split)
##
## Node number 10: 10462 observations, complexity param=0.05987531
##   predicted class=A expected loss=0.7167846 P(node) =0.7108303
##   class counts: 2963 1898 2490 1985 1126
##   probabilities: 0.283 0.181 0.238 0.190 0.108
##   left son=20 (6480 obs) right son=21 (3982 obs)
## Primary splits:
##   roll_forearm < 123.5 to the left, improve=366.3309, (0 missing)

```

```

##      yaw_belt           < 169.5    to the right, improve=317.5318, (0 missing)
##      magnet_dumbbell_z < -17.5    to the left,  improve=283.0673, (0 missing)
##      accel_dumbbell_y  < -40.5    to the right, improve=247.3432, (0 missing)
##      roll_arm           < -60.75   to the left,  improve=233.7621, (0 missing)
## Surrogate splits:
##      total_accel_dumbbell < 22.5    to the left,  agree=0.726, adj=0.280, (0 split)
##      accel_dumbbell_x     < -65.5    to the right, agree=0.724, adj=0.274, (0 split)
##      roll_belt            < 1.315    to the right, agree=0.723, adj=0.272, (0 split)
##      accel_belt_z          < -3.5    to the left,  agree=0.722, adj=0.268, (0 split)
##      yaw_forearm           < 64.9    to the left,  agree=0.721, adj=0.267, (0 split)
##
## Node number 11: 1858 observations,    complexity param=0.02990601
##   predicted class=B expected loss=0.4908504 P(node) =0.12624
##   class counts:  53  946   77  427   355
##   probabilities: 0.029 0.509 0.041 0.230 0.191
##   left son=22 (1315 obs) right son=23 (543 obs)
## Primary splits:
##      total_accel_dumbbell < 5.5    to the right, improve=298.3218, (0 missing)
##      accel_dumbbell_y      < 46.5   to the right, improve=254.0723, (0 missing)
##      yaw_belt               < -2.825 to the left,  improve=229.3211, (0 missing)
##      roll_belt              < -0.58  to the right, improve=224.4949, (0 missing)
##      magnet_belt_z          < -326.5 to the right, improve=207.8074, (0 missing)
## Surrogate splits:
##      accel_dumbbell_y < 45.5    to the right, agree=0.968, adj=0.891, (0 split)
##      yaw_belt             < -3.37  to the left,  agree=0.842, adj=0.459, (0 split)
##      accel_forearm_x       < -293.5 to the right, agree=0.827, adj=0.407, (0 split)
##      roll_belt              < 117.5 to the left,  agree=0.818, adj=0.376, (0 split)
##      accel_belt_y          < 48.5   to the left,  agree=0.816, adj=0.372, (0 split)
##
## Node number 20: 6480 observations,    complexity param=0.02212095
##   predicted class=A expected loss=0.5921296 P(node) =0.4402772
##   class counts:  2643  1183  1171  1093   390
##   probabilities: 0.408 0.183 0.181 0.169 0.060
##   left son=40 (2237 obs) right son=41 (4243 obs)
## Primary splits:
##      magnet_dumbbell_z < -25.5   to the left,  improve=349.5423, (0 missing)
##      roll_forearm         < -131.5 to the right, improve=298.4516, (0 missing)
##      accel_dumbbell_y     < -40.5  to the right, improve=289.6267, (0 missing)
##      pitch_belt            < 15.35 to the right, improve=231.0545, (0 missing)
##      yaw_belt              < 169.5 to the right, improve=211.3985, (0 missing)
## Surrogate splits:
##      pitch_belt           < 15.25  to the right, agree=0.882, adj=0.657, (0 split)
##      accel_belt_x          < -19.5  to the left,  agree=0.842, adj=0.543, (0 split)
##      magnet_belt_x          < 25.5  to the left,  agree=0.826, adj=0.495, (0 split)
##      accel_belt_y           < 55.5  to the right, agree=0.821, adj=0.481, (0 split)
##      roll_forearm           < 0.005 to the right, agree=0.772, adj=0.339, (0 split)
##
## Node number 21: 3982 observations,    complexity param=0.03446312
##   predicted class=C expected loss=0.6687594 P(node) =0.2705531
##   class counts:  320   715  1319  892   736
##   probabilities: 0.080 0.180 0.331 0.224 0.185
##   left son=42 (2330 obs) right son=43 (1652 obs)
## Primary splits:
##      magnet_dumbbell_y < 291.5   to the left,  improve=192.7161, (0 missing)

```

```

##      accel_forearm_x   < -107.5    to the right, improve=183.4029, (0 missing)
##      magnet_arm_y       < 272.5     to the right, improve=168.3041, (0 missing)
##      magnet_forearm_z   < -251      to the left,  improve=163.5566, (0 missing)
##      magnet_dumbbell_z < 286.5     to the right, improve=160.0265, (0 missing)
## Surrogate splits:
##      roll_dumbbell      < 20.87401  to the left,  agree=0.828, adj=0.585, (0 split)
##      accel_dumbbell_y   < 17.5      to the left,  agree=0.822, adj=0.570, (0 split)
##      total_accel_dumbbell < 15.5     to the left,  agree=0.754, adj=0.406, (0 split)
##      accel_dumbbell_z   < -104     to the right, agree=0.711, adj=0.303, (0 split)
##      accel_dumbbell_x   < -87.5     to the right, agree=0.709, adj=0.300, (0 split)
##
## Node number 22: 1315 observations,    complexity param=0.01955758
##   predicted class=B  expected loss=0.3437262 P(node) =0.08934638
##   class counts:    53    863    75    29    295
##   probabilities: 0.040  0.656  0.057  0.022  0.224
##   left son=44 (1109 obs) right son=45 (206 obs)
## Primary splits:
##      roll_belt          < -0.58     to the right, improve=253.47770, (0 missing)
##      gyros_belt_z        < -0.255    to the right, improve=133.11020, (0 missing)
##      magnet_belt_z       < -287.5    to the left,  improve=108.67430, (0 missing)
##      accel_belt_y        < -1.5      to the right, improve= 98.78198, (0 missing)
##      magnet_dumbbell_z < 17.5      to the left,  improve= 98.25329, (0 missing)
## Surrogate splits:
##      magnet_belt_z < -286.5     to the left,  agree=0.911, adj=0.432, (0 split)
##      accel_belt_y < -1.5       to the right, agree=0.900, adj=0.359, (0 split)
##      gyros_belt_y < -0.04      to the right, agree=0.873, adj=0.189, (0 split)
##      magnet_belt_x < -7.5      to the right, agree=0.870, adj=0.170, (0 split)
##      gyros_belt_z < -0.27      to the right, agree=0.868, adj=0.160, (0 split)
##
## Node number 23: 543 observations
##   predicted class=D  expected loss=0.267035 P(node) =0.0368936
##   class counts:     0     83     2    398    60
##   probabilities: 0.000  0.153  0.004  0.733  0.110
##
## Node number 40: 2237 observations,    complexity param=0.01101301
##   predicted class=A  expected loss=0.3330353 P(node) =0.1519908
##   class counts:  1492    453     42    181     69
##   probabilities: 0.667  0.203  0.019  0.081  0.031
##   left son=80 (1859 obs) right son=81 (378 obs)
## Primary splits:
##      roll_forearm      < -136.5    to the right, improve=207.2354, (0 missing)
##      accel_dumbbell_y < -50.5      to the right, improve=145.0686, (0 missing)
##      magnet_forearm_z < 181.5     to the right, improve=125.2758, (0 missing)
##      magnet_forearm_y < -258.5    to the right, improve=118.6775, (0 missing)
##      gyros_arm_x        < -3.165   to the right, improve=116.4885, (0 missing)
## Surrogate splits:
##      magnet_forearm_y < -371.5    to the right, agree=0.911, adj=0.471, (0 split)
##      magnet_forearm_z < 181.5     to the right, agree=0.903, adj=0.426, (0 split)
##      accel_forearm_z   < -203.5    to the right, agree=0.893, adj=0.365, (0 split)
##      gyros_arm_x        < -3.19     to the right, agree=0.877, adj=0.272, (0 split)
##      gyros_arm_y        < 1.34      to the left,  agree=0.868, adj=0.217, (0 split)
##
## Node number 41: 4243 observations,    complexity param=0.02212095
##   predicted class=A  expected loss=0.7287297 P(node) =0.2882865

```

```

##      class counts: 1151    730   1129   912    321
##      probabilities: 0.271 0.172 0.266 0.215 0.076
##      left son=82 (577 obs) right son=83 (3666 obs)
##      Primary splits:
##          yaw_belt      < 168.5      to the right, improve=291.4081, (0 missing)
##          accel_dumbbell_y < -40.5      to the right, improve=273.5031, (0 missing)
##          pitch_belt     < -42.45     to the left,  improve=228.4282, (0 missing)
##          roll_dumbbell   < -88.98732   to the right, improve=199.9125, (0 missing)
##          yaw_arm        < -115       to the left,  improve=180.6568, (0 missing)
##      Surrogate splits:
##          pitch_belt     < -43.55     to the left,  agree=0.910, adj=0.336, (0 split)
##          pitch_arm       < 68.15      to the right, agree=0.881, adj=0.125, (0 split)
##          magnet_belt_x   < 193.5      to the right, agree=0.870, adj=0.043, (0 split)
##          magnet_arm_y    < 491        to the right, agree=0.869, adj=0.038, (0 split)
##          gyros_forearm_x < 1.95      to the right, agree=0.866, adj=0.016, (0 split)
##
## Node number 42: 2330 observations,    complexity param=0.0143359
##   predicted class=C expected loss=0.5145923 P(node) =0.1583096
##   class counts: 224    306   1131   341    328
##   probabilities: 0.096 0.131 0.485 0.146 0.141
##   left son=84 (187 obs) right son=85 (2143 obs)
##   Primary splits:
##       magnet_forearm_z < -251      to the left,  improve=154.6147, (0 missing)
##       magnet_dumbbell_z < 286.5      to the right, improve=150.3559, (0 missing)
##       magnet_forearm_y < 841        to the right, improve=134.6032, (0 missing)
##       accel_forearm_z   < -168.5     to the right, improve=116.7137, (0 missing)
##       gyros_dumbbell_y  < -0.25      to the left,  improve=102.8975, (0 missing)
##   Surrogate splits:
##       magnet_forearm_y < 815.5      to the right, agree=0.983, adj=0.786, (0 split)
##       accel_forearm_z   < 195.5      to the right, agree=0.930, adj=0.123, (0 split)
##       magnet_forearm_x   < -720.5     to the left,  agree=0.927, adj=0.086, (0 split)
##       pitch_forearm      < -22.7      to the left,  agree=0.926, adj=0.080, (0 split)
##       gyros_dumbbell_x   < -1.095     to the left,  agree=0.925, adj=0.070, (0 split)
##
## Node number 43: 1652 observations,    complexity param=0.02050698
##   predicted class=D expected loss=0.6664649 P(node) =0.1122435
##   class counts: 96     409   188    551    408
##   probabilities: 0.058 0.248 0.114 0.334 0.247
##   left son=86 (1070 obs) right son=87 (582 obs)
##   Primary splits:
##       accel_forearm_x   < -101.5     to the right, improve=162.8788, (0 missing)
##       pitch_forearm      < 23.85      to the left,  improve=136.9468, (0 missing)
##       magnet_dumbbell_x   < -84.5      to the right, improve=115.0028, (0 missing)
##       magnet_forearm_x   < -516       to the right, improve=110.6594, (0 missing)
##       accel_dumbbell_x   < 96         to the right, improve=109.4126, (0 missing)
##   Surrogate splits:
##       pitch_forearm      < 23.35      to the left,  agree=0.873, adj=0.641, (0 split)
##       magnet_forearm_x   < -514.5     to the right, agree=0.835, adj=0.531, (0 split)
##       yaw_forearm        < 118.5      to the left,  agree=0.781, adj=0.380, (0 split)
##       magnet_dumbbell_z   < -9.5       to the right, agree=0.683, adj=0.100, (0 split)
##       accel_forearm_z   < -173.5     to the right, agree=0.676, adj=0.081, (0 split)
##
## Node number 44: 1109 observations
##   predicted class=B expected loss=0.2218215 P(node) =0.07534991

```

```

##      class counts:    53    863     75     29     89
##      probabilities: 0.048 0.778 0.068 0.026 0.080
##
## Node number 45: 206 observations
##   predicted class=E  expected loss=0  P(node) =0.01399647
##      class counts:      0      0      0      0    206
##      probabilities: 0.000 0.000 0.000 0.000 1.000
##
## Node number 80: 1859 observations
##   predicted class=A  expected loss=0.2157074  P(node) =0.1263079
##      class counts:  1458    303     38     52      8
##      probabilities: 0.784 0.163 0.020 0.028 0.004
##
## Node number 81: 378 observations
##   predicted class=B  expected loss=0.6031746  P(node) =0.02568284
##      class counts:    34    150      4    129     61
##      probabilities: 0.090 0.397 0.011 0.341 0.161
##
## Node number 82: 577 observations
##   predicted class=A  expected loss=0.1542461  P(node) =0.0392037
##      class counts:  488     50      0     36      3
##      probabilities: 0.846 0.087 0.000 0.062 0.005
##
## Node number 83: 3666 observations,    complexity param=0.02212095
##   predicted class=C  expected loss=0.6920349  P(node) =0.2490828
##      class counts:  663    680   1129    876    318
##      probabilities: 0.181 0.185 0.308 0.239 0.087
##   left son=166 (3160 obs) right son=167 (506 obs)
## Primary splits:
##   accel_dumbbell_y < -40.5      to the right, improve=236.0154, (0 missing)
##   pitch_belt        < -43.15     to the left,  improve=222.9071, (0 missing)
##   yaw_arm           < -119.5     to the left,  improve=176.4524, (0 missing)
##   magnet_forearm_x < 277.5      to the right, improve=164.9657, (0 missing)
##   roll_dumbbell     < -88.98732 to the left,  improve=161.5066, (0 missing)
## Surrogate splits:
##   roll_dumbbell     < -90.25149 to the right, agree=0.948, adj=0.621, (0 split)
##   accel_belt_y      < 53.5       to the left,  agree=0.940, adj=0.567, (0 split)
##   pitch_belt         < 11.13      to the left,  agree=0.930, adj=0.494, (0 split)
##   magnet_dumbbell_y < 401.5      to the left,  agree=0.919, adj=0.411, (0 split)
##   pitch_dumbbell    < -38.15474 to the right, agree=0.883, adj=0.150, (0 split)
##
## Node number 84: 187 observations
##   predicted class=A  expected loss=0.1925134  P(node) =0.01270553
##      class counts:  151     15      0      7     14
##      probabilities: 0.807 0.080 0.000 0.037 0.075
##
## Node number 85: 2143 observations
##   predicted class=C  expected loss=0.4722352  P(node) =0.145604
##      class counts:   73    291   1131    334    314
##      probabilities: 0.034 0.136 0.528 0.156 0.147
##
## Node number 86: 1070 observations,    complexity param=0.01898794
##   predicted class=E  expected loss=0.6616822  P(node) =0.0727001
##      class counts:   56    335   171    146    362

```

```

##      probabilities: 0.052 0.313 0.160 0.136 0.338
##      left son=172 (456 obs) right son=173 (614 obs)
## Primary splits:
##      magnet_arm_y < 188.5      to the right, improve=92.42856, (0 missing)
##      accel_arm_x < -97.5      to the left,  improve=79.86755, (0 missing)
##      accel_arm_y < 150.5      to the right, improve=77.97171, (0 missing)
##      accel_dumbbell_x < 109      to the right, improve=73.65961, (0 missing)
##      magnet_dumbbell_x < 39.5      to the right, improve=72.85758, (0 missing)
## Surrogate splits:
##      accel_arm_x < -107.5      to the left,  agree=0.965, adj=0.919, (0 split)
##      magnet_arm_x < 268.5      to the left,  agree=0.938, adj=0.855, (0 split)
##      accel_arm_y < 153.5      to the right, agree=0.889, adj=0.739, (0 split)
##      magnet_arm_z < 352.5      to the right, agree=0.831, adj=0.603, (0 split)
##      pitch_arm < -9.89      to the right, agree=0.757, adj=0.430, (0 split)
##
## Node number 87: 582 observations
##   predicted class=D expected loss=0.3041237 P(node) =0.03954342
##   class counts:    40     74     17    405     46
##   probabilities: 0.069 0.127 0.029 0.696 0.079
##
## Node number 166: 3160 observations,   complexity param=0.02212095
##   predicted class=D expected loss=0.7287975 P(node) =0.2147031
##   class counts:   658    656    691    857    298
##   probabilities: 0.208 0.208 0.219 0.271 0.094
##   left son=332 (382 obs) right son=333 (2778 obs)
## Primary splits:
##      pitch_belt < -42.85      to the left,  improve=212.5951, (0 missing)
##      yaw_arm < -119.5      to the left,  improve=164.0981, (0 missing)
##      roll_belt < 125.5      to the right, improve=156.0609, (0 missing)
##      magnet_forearm_x < 277.5      to the right, improve=148.9868, (0 missing)
##      accel_forearm_x < 59.5      to the right, improve=139.7594, (0 missing)
## Surrogate splits:
##      yaw_belt < 166.5      to the right, agree=0.897, adj=0.147, (0 split)
##      accel_arm_z < 91.5      to the right, agree=0.885, adj=0.052, (0 split)
##      pitch_arm < -79.8      to the left,  agree=0.884, adj=0.039, (0 split)
##      gyros_dumbbell_y < 1.07      to the right, agree=0.881, adj=0.013, (0 split)
##      accel_belt_x < 64.5      to the right, agree=0.880, adj=0.008, (0 split)
##
## Node number 167: 506 observations
##   predicted class=C expected loss=0.1343874 P(node) =0.03437967
##   class counts:     5     24    438     19     20
##   probabilities: 0.010 0.047 0.866 0.038 0.040
##
## Node number 172: 456 observations
##   predicted class=B expected loss=0.4561404 P(node) =0.03098247
##   class counts:     8    248    108     44     48
##   probabilities: 0.018 0.544 0.237 0.096 0.105
##
## Node number 173: 614 observations
##   predicted class=E expected loss=0.4885993 P(node) =0.04171762
##   class counts:    48     87     63    102    314
##   probabilities: 0.078 0.142 0.103 0.166 0.511
##
## Node number 332: 382 observations

```

```

##   predicted class=B  expected loss=0.1780105  P(node) =0.02595461
##   class counts:    10     314     39     10      9
##   probabilities: 0.026  0.822  0.102  0.026  0.024
##
## Node number 333: 2778 observations,    complexity param=0.02212095
##   predicted class=D  expected loss=0.6951044  P(node) =0.1887485
##   class counts:   648     342     652     847     289
##   probabilities: 0.233  0.123  0.235  0.305  0.104
## left son=666 (652 obs) right son=667 (2126 obs)
## Primary splits:
##   roll_belt      < 125.5      to the right, improve=218.5179, (0 missing)
##   yaw_arm        < -117.5     to the left,  improve=152.4924, (0 missing)
##   accel_dumbbell_z < 21.5      to the left,  improve=148.8859, (0 missing)
##   magnet_forearm_x < -188.5    to the right, improve=146.4507, (0 missing)
##   accel_forearm_x < -70.5      to the right, improve=144.7157, (0 missing)
## Surrogate splits:
##   accel_belt_z   < -159.5     to the left,  agree=0.900, adj=0.572, (0 split)
##   total_accel_belt < 17.5      to the right, agree=0.882, adj=0.495, (0 split)
##   magnet_belt_x   < 165.5      to the right, agree=0.839, adj=0.316, (0 split)
##   yaw_dumbbell    < -95.52705  to the left,  agree=0.816, adj=0.216, (0 split)
##   magnet_forearm_x < 624.5      to the right, agree=0.814, adj=0.206, (0 split)
##
## Node number 666: 652 observations,    complexity param=0.01898794
##   predicted class=C  expected loss=0.4003067  P(node) =0.0442995
##   class counts:   238      11     391      9      3
##   probabilities: 0.365  0.017  0.600  0.014  0.005
## left son=1332 (209 obs) right son=1333 (443 obs)
## Primary splits:
##   magnet_belt_z   < -323.5     to the left,  improve=218.6271, (0 missing)
##   pitch_belt       < -40.45     to the right, improve=201.6756, (0 missing)
##   magnet_dumbbell_z < 24.5      to the left,  improve=189.0210, (0 missing)
##   roll_belt        < 128.5      to the right, improve=166.3526, (0 missing)
##   magnet_forearm_x < 263.5      to the right, improve=132.3928, (0 missing)
## Surrogate splits:
##   roll_belt        < 128.5      to the right, agree=0.926, adj=0.770, (0 split)
##   pitch_belt       < -40.45     to the right, agree=0.923, adj=0.761, (0 split)
##   accel_belt_z    < -164.5     to the left,  agree=0.888, adj=0.651, (0 split)
##   accel_forearm_y < 255.5      to the left,  agree=0.887, adj=0.646, (0 split)
##   magnet_forearm_x < 263.5      to the right, agree=0.887, adj=0.646, (0 split)
##
## Node number 667: 2126 observations,    complexity param=0.01063325
##   predicted class=D  expected loss=0.6058325  P(node) =0.1444449
##   class counts:   410     331     261     838     286
##   probabilities: 0.193  0.156  0.123  0.394  0.135
## left son=1334 (1344 obs) right son=1335 (782 obs)
## Primary splits:
##   pitch_belt       < 1.04      to the right, improve=154.2258, (0 missing)
##   yaw_belt         < -87.05    to the left,  improve=145.1140, (0 missing)
##   gyros_belt_z    < -0.105    to the right, improve=128.2870, (0 missing)
##   accel_dumbbell_z < 27.5      to the left,  improve=125.4258, (0 missing)
##   accel_belt_z    < -2.5      to the right, improve=121.3720, (0 missing)
## Surrogate splits:
##   accel_belt_x    < -0.5      to the left,  agree=0.939, adj=0.834, (0 split)
##   yaw_belt        < -85.55    to the left,  agree=0.924, adj=0.793, (0 split)

```

```

##      magnet_belt_x < 77.5      to the left,  agree=0.924, adj=0.793, (0 split)
##      gyros_belt_z  < -0.105    to the right, agree=0.903, adj=0.735, (0 split)
##      accel_belt_z  < -7.5     to the right, agree=0.897, adj=0.721, (0 split)
##
## Node number 1332: 209 observations
##   predicted class=A  expected loss=0.02870813  P(node) =0.0142003
##   class counts:  203     0     3     0     3
##   probabilities: 0.971 0.000 0.014 0.000 0.014
##
## Node number 1333: 443 observations
##   predicted class=C  expected loss=0.1241535  P(node) =0.0300992
##   class counts:  35     11   388     9     0
##   probabilities: 0.079 0.025 0.876 0.020 0.000
##
## Node number 1334: 1344 observations,   complexity param=0.01063325
##   predicted class=B  expected loss=0.764881  P(node) =0.09131675
##   class counts:  308    316   175   291   254
##   probabilities: 0.229 0.235 0.130 0.217 0.189
##   left son=2668 (846 obs) right son=2669 (498 obs)
## Primary splits:
##   accel_dumbbell_z < 27.5      to the left,  improve=117.73090, (0 missing)
##   yaw_forearm       < -94.65    to the right, improve=102.87940, (0 missing)
##   magnet_forearm_z < -56.5     to the right, improve= 86.79337, (0 missing)
##   yaw_belt          < -93.25    to the right, improve= 82.22818, (0 missing)
##   pitch_forearm    < 3.805     to the left,  improve= 81.91731, (0 missing)
## Surrogate splits:
##   magnet_dumbbell_z < 334.5     to the left,  agree=0.825, adj=0.528, (0 split)
##   accel_dumbbell_x < 13.5      to the left,  agree=0.804, adj=0.472, (0 split)
##   yaw_dumbbell      < 55.59403  to the left,  agree=0.795, adj=0.446, (0 split)
##   gyros_dumbbell_x < -0.215    to the right, agree=0.783, adj=0.414, (0 split)
##   total_accel_dumbbell < 5.5    to the left,  agree=0.774, adj=0.390, (0 split)
##
## Node number 1335: 782 observations
##   predicted class=D  expected loss=0.3005115  P(node) =0.05313222
##   class counts:  102     15    86   547    32
##   probabilities: 0.130 0.019 0.110 0.699 0.041
##
## Node number 2668: 846 observations,   complexity param=0.01063325
##   predicted class=A  expected loss=0.6560284  P(node) =0.05748064
##   class counts:  291    128   172   225    30
##   probabilities: 0.344 0.151 0.203 0.266 0.035
##   left son=5336 (618 obs) right son=5337 (228 obs)
## Primary splits:
##   yaw_forearm       < -94.65    to the right, improve=122.90840, (0 missing)
##   magnet_dumbbell_y < 263.5     to the right, improve=102.14100, (0 missing)
##   magnet_forearm_z < -174      to the right, improve= 96.96084, (0 missing)
##   accel_forearm_x  < -3.5      to the right, improve= 91.84190, (0 missing)
##   pitch_forearm    < 22.9      to the left,  improve= 89.29766, (0 missing)
## Surrogate splits:
##   yaw_belt          < -93.15    to the right, agree=0.859, adj=0.478, (0 split)
##   accel_forearm_x < -106.5    to the right, agree=0.852, adj=0.452, (0 split)
##   pitch_forearm   < 28.75     to the left,  agree=0.845, adj=0.425, (0 split)
##   accel_forearm_z < -162.5    to the right, agree=0.824, adj=0.346, (0 split)
##   magnet_belt_x    < 7.5       to the right, agree=0.817, adj=0.320, (0 split)

```

```

## 
## Node number 2669: 498 observations,    complexity param=0.01044337
##   predicted class=E  expected loss=0.5502008 P(node) =0.03383612
##   class counts:    17   188    3   66   224
##   probabilities: 0.034 0.378 0.006 0.133 0.450
##   left son=5338 (310 obs) right son=5339 (188 obs)
## Primary splits:
##   roll_dumbbell < 53.36059  to the left,  improve=80.46827, (0 missing)
##   magnet_belt_x < 43.5      to the left,  improve=53.16063, (0 missing)
##   yaw_belt       < -88.15    to the left,  improve=47.82673, (0 missing)
##   yaw_dumbbell   < 101.1489  to the right, improve=34.62069, (0 missing)
##   yaw_forearm    < 115.5     to the left,  improve=34.37824, (0 missing)
## Surrogate splits:
##   yaw_dumbbell    < 101.1489 to the right, agree=0.819, adj=0.521, (0 split)
##   accel_dumbbell_y < 66.5     to the left,  agree=0.767, adj=0.383, (0 split)
##   gyros_dumbbell_z < 0.04     to the left,  agree=0.705, adj=0.218, (0 split)
##   accel_forearm_y < 253.5    to the right, agree=0.701, adj=0.207, (0 split)
##   accel_dumbbell_z < 41.5     to the right, agree=0.693, adj=0.186, (0 split)
##
## Node number 5336: 618 observations,    complexity param=0.01063325
##   predicted class=A  expected loss=0.5291262 P(node) =0.0419894
##   class counts:    291   119   137    48    23
##   probabilities: 0.471 0.193 0.222 0.078 0.037
##   left son=10672 (382 obs) right son=10673 (236 obs)
## Primary splits:
##   magnet_forearm_z   < -68.5     to the right, improve=116.49450, (0 missing)
##   magnet_dumbbell_y  < 263.5     to the right, improve= 94.66525, (0 missing)
##   accel_forearm_y    < 238       to the left,  improve= 88.68775, (0 missing)
##   total_accel_forearm < 36.5     to the left,  improve= 87.29102, (0 missing)
##   magnet_forearm_y   < 811       to the left,  improve= 84.16128, (0 missing)
## Surrogate splits:
##   magnet_forearm_y  < 811       to the left,  agree=0.874, adj=0.669, (0 split)
##   magnet_dumbbell_y < 238.5     to the right, agree=0.871, adj=0.661, (0 split)
##   roll_forearm       < -168.5    to the right, agree=0.866, adj=0.648, (0 split)
##   accel_forearm_z   < 179.5     to the left,  agree=0.832, adj=0.559, (0 split)
##   accel_forearm_y   < 261.5     to the left,  agree=0.812, adj=0.508, (0 split)
##
## Node number 5337: 228 observations
##   predicted class=D  expected loss=0.2236842 P(node) =0.01549124
##   class counts:      0     9    35   177     7
##   probabilities: 0.000 0.039 0.154 0.776 0.031
##
## Node number 5338: 310 observations
##   predicted class=B  expected loss=0.4483871 P(node) =0.02106264
##   class counts:    16   171     3    59    61
##   probabilities: 0.052 0.552 0.010 0.190 0.197
##
## Node number 5339: 188 observations
##   predicted class=E  expected loss=0.1329787 P(node) =0.01277347
##   class counts:     1    17     0     7   163
##   probabilities: 0.005 0.090 0.000 0.037 0.867
##
## Node number 10672: 382 observations
##   predicted class=A  expected loss=0.2670157 P(node) =0.02595461

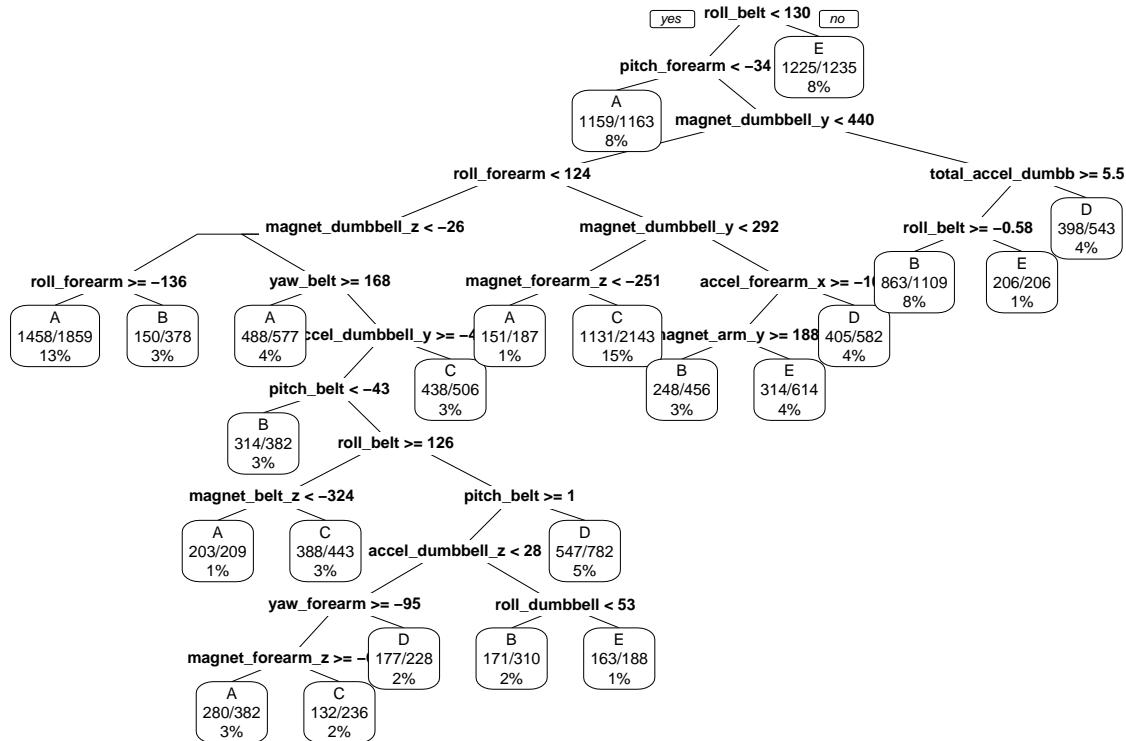
```

```

##      class counts: 280    52     5    39     6
##      probabilities: 0.733 0.136 0.013 0.102 0.016
##
## Node number 10673: 236 observations
##      predicted class=C expected loss=0.440678 P(node) =0.01603479
##      class counts: 11     67    132     9    17
##      probabilities: 0.047 0.284 0.559 0.038 0.072
# Predicting using subTesting data
prediction <- predict(decisiontreemodel, subTesting, type = "class")

# Plot of the Decision Tree: decisiontreemode1
prp(decisiontreemode1, faclen = 0, cex = 0.5, extra = 102, xsep="/")

```



```

## Overall Statistics
##
##          Accuracy : 0.7394
##                95% CI : (0.7269, 0.7516)
##    No Information Rate : 0.2845
##    P-Value [Acc > NIR] : < 2.2e-16
##
##          Kappa : 0.6697
## McNemar's Test P-Value : < 2.2e-16
##
## Statistics by Class:
##
##           Class: A Class: B Class: C Class: D Class: E
## Sensitivity          0.8853   0.5985   0.8070   0.6318   0.6937
## Specificity          0.9307   0.9216   0.9005   0.9529   0.9678
## Pos Pred Value       0.8356   0.6469   0.6313   0.7247   0.8289
## Neg Pred Value       0.9533   0.9054   0.9567   0.9296   0.9335
## Prevalence           0.2845   0.1935   0.1743   0.1639   0.1837
## Detection Rate       0.2518   0.1158   0.1407   0.1036   0.1274
## Detection Prevalence 0.3014   0.1790   0.2229   0.1429   0.1538
## Balanced Accuracy    0.9080   0.7601   0.8537   0.7924   0.8307

```

RESULTS of Decision tree Model: Results from confusionMatrix reported prediction accuracy 0.7372 (95%

4b. Second Prediction model with RandomForests

```

# Using RandomForest
rftreemodel <- randomForest(classe ~ ., data=subTraining, method="class")

# Predicting using subTesting data
prediction1 <- predict(rftreemodel, subTesting, type = "class")

# Test results on subTesting data set:
confusionMatrix(prediction1, subTesting$classe)

```

```

## Confusion Matrix and Statistics
##
##          Reference
## Prediction   A     B     C     D     E
##           A 1395    3    0    0    0
##           B    0  943   10    0    0
##           C    0     3  844    5    0
##           D    0     0     1  799    0
##           E    0     0     0     0  901
##
## Overall Statistics
##
##          Accuracy : 0.9955
##                95% CI : (0.9932, 0.9972)
##    No Information Rate : 0.2845
##    P-Value [Acc > NIR] : < 2.2e-16
##
```

```

##                               Kappa : 0.9943
##   Mcnemar's Test P-Value : NA
##
## Statistics by Class:
##
##                               Class: A Class: B Class: C Class: D Class: E
## Sensitivity                  1.0000   0.9937   0.9871   0.9938   1.0000
## Specificity                  0.9991   0.9975   0.9980   0.9998   1.0000
## Pos Pred Value                0.9979   0.9895   0.9906   0.9988   1.0000
## Neg Pred Value                1.0000   0.9985   0.9973   0.9988   1.0000
## Prevalence                     0.2845   0.1935   0.1743   0.1639   0.1837
## Detection Rate                 0.2845   0.1923   0.1721   0.1629   0.1837
## Detection Prevalence          0.2851   0.1943   0.1737   0.1631   0.1837
## Balanced Accuracy              0.9996   0.9956   0.9926   0.9968   1.0000

# Results from confusionMatrix reported prediction accuracy 0.9947 (95% CI 0.9922, 0.9965)

# **RESULT**: When comparing the RESULTS from rpart (decision tree) and RandomForest Model, RandomForest

# The given test dataset comprises 53 variables and 20 obs. With a prediction accuracy of RandomForest

# predict outcome levels on the main Testing dataset using Random Forest algorithm
predictionfinal <- predict(rftreemodel, testdataset, type="class")

# plot prediction final results
plot(predictionfinal)

```

