Human Activity Recognition Using Machine Learning

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I. Introduction

Human Activity Recognition - HAR - has emerged as a key research area in the last few years and is gaining increasing attention.

This particular data analysis attempts to accurately predict a particular human activity (Unilateral Dumbbell Biceps Curl) using the data from from a human activity research at http://groupware.les.inf.puc-rio.br/har (Please see this webpage for detailed information). This dataset is licensed under the Creative Commons license (CC BY-SA). The research has been conducted by observing six young adults perfom these activities while recording the data from thier arm, belt, forearm and dumbbell sensors.

Goal / Prediction / Dependent Variable: THE ACTIVITY PERFORMED. Unilateral Dumbbell Biceps Curl in five different types (ways): exactly according to the specification (Class A), throwing the elbows to the front (Class B), lifting the dumbbell only halfway (Class C), lowering the dumbbell only halfway (Class D) and throwing the hips to the front (Class E).

Predictors / Independent Variables: SENSOR INFORMATION. Arm sensor orientation variables, Belt sensor orientation variables, Forearm sensor orientation variables and Dumbbell sensor orientation variables (all on the X, Y and Z axes)

II. Executive Summary

The Unilateral Dumbbell Biceps Curl activity type (as classified by A, B, C,D and E) is predicted using **Random Forest modelling with 10 fold cross validation**. The prediction model has an **Out of Sample Error rate of 0.365%**. A low Out of Sample Error rate also signifies that the over-fitting has not occurred.

The model has been selected after cleaning, exploring and applying various models of CART, Boosting, Random Forest and Linear Discriminant Analysis and comparing thier results.

The Random Forest model accuracy is limited to the *six young adults* who participated in the research. Application outside of this limitation will not be reliable.

There is also futher scope to use Kappa and ROC for model comparison and selection (possibly between Boosting and Randon Forest for this data set).

III. Data Analysis

1. Getting the Data

The data for analysis is downloaded from http://d396qusza40orc.cloudfront.net/predmachlearn. The below code downloads the file, saves it and then reads the data into R.

The training.csv file is used for the predictive modelling through outin this analysis.

The selected prediction model is then applied on the testing.csv file and the result uploaded in Coursera Machine Learning Class project.

```
setwd ("C:/Users/KanthimathiGayatri/Desktop/ML")

trainingFile = "./pml-training.csv"
if (!file.exists (trainingFile))
    download.file ("http://d396qusza40orc.cloudfront.net/predmachlearn/pml-training.csv", trainingFile)
training = read.csv (trainingFile)

testingFile = "./pml-testing.csv"
if (!file.exists (testingFile))
    download.file ("http://d396qusza40orc.cloudfront.net/predmachlearn/pml-testing.csv", testingFile)
testing = read.csv (testingFile)

#Size of training data
dim (training)
```

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

```
#Size of testing data
dim (testing)
```

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

2. Splitting the data into train and test samples

We will split the *training.csv* data into our own training and test sample sets in the proportion of 70:30 over the prediction variable *classe* (denotes the activity type).

We will also set the pseudo random number for the purpose of reproducibility.

```
set.seed (12345)
inTrain = createDataPartition (y = training$classe, p = 0.7, list = FALSE)
myTrain = training [inTrain, ]
myTest = training [-inTrain, ]
dim(myTrain); dim(myTest)
```

```
## [1] 13737   160
```

```
## [1] 5885  160
```

Dataset **myTrain** represents the train data and **myTest** the test data. With this, we will set **myTest** aside until models are ready to be tested.

3. Cleaning the Data

[At several places during cleaning, the results are hidden due to the verbosity. However, the summary of the data before and after the cleaning are added to the appendix for reference]

Let us print the summary of the data to understand it better.

```
summary(myTrain)
#Hiding the results due to verbosity...
```

From the summary it appears that for a few variables, there are 13439 NA fields (out of 13737 fields) identically.

```
head (myTrain, 50)
#Hiding the results due to verbosity...
```

The results shows that the NAs exist only whereever the *new_window* variable is "yes". Thats about 298 records (~2%).

Let us remove these 298 rows and the columns with all NAs for our modelling. A better approach would be to create a separate model for these removed 298 rows that are data rich.

```
myCleanTrain = subset (myTrain, new_window == "no")

naVecs = colSums (is.na (myCleanTrain)) < nrow (myCleanTrain)
myCleanTrain = myCleanTrain [ , naVecs]
```

Next, let us look for near zero variance variables that will not be of use for modelling and remove these.

```
nzv = nearZeroVar (myCleanTrain) #saveMetrics was TRUE during exploration.
myCleanTrain = subset (myCleanTrain, select = -(nzv))
```

We will also remove the variables that are not relavant for the prediction of the activity type, the *classe* variable.

```
# Remove variables X, user_name, raw_timestamp_part_1, raw_timestamp_part_2 and cvtd_timestamp. Not rel
myCleanTrain = subset (myCleanTrain, select = -(X:cvtd_timestamp))
```

Let us now check the final cleaned variable names -

```
names(myCleanTrain)
```

```
##  [1] "num_window"           "roll_belt"            "pitch_belt"
##  [4] "yaw_belt"             "total_accel_belt"     "gyros_belt_x"
##  [7] "gyros_belt_y"         "gyros_belt_z"         "accel_belt_x"
## [10] "accel_belt_y"         "accel_belt_z"         "magnet_belt_x"
## [13] "magnet_belt_y"        "magnet_belt_z"        "roll_arm"
## [16] "pitch_arm"            "yaw_arm"              "total_accel_arm"
## [19] "gyros_arm_x"          "gyros_arm_y"          "gyros_arm_z"
## [22] "accel_arm_x"          "accel_arm_y"          "accel_arm_z"
## [25] "magnet_arm_x"         "magnet_arm_y"         "magnet_arm_z"
## [28] "roll_dumbbell"        "pitch_dumbbell"       "yaw_dumbbell"
## [31] "total_accel_dumbbell" "gyros_dumbbell_x"     "gyros_dumbbell_y"
## [34] "gyros_dumbbell_z"     "accel_dumbbell_x"     "accel_dumbbell_y"
## [37] "accel_dumbbell_z"     "magnet_dumbbell_x"    "magnet_dumbbell_y"
## [40] "magnet_dumbbell_z"    "roll_forearm"         "pitch_forearm"
## [43] "yaw_forearm"          "total_accel_forearm"  "gyros_forearm_x"
## [46] "gyros_forearm_y"      "gyros_forearm_z"      "accel_forearm_x"
## [49] "accel_forearm_y"      "accel_forearm_z"      "magnet_forearm_x"
## [52] "magnet_forearm_y"     "magnet_forearm_z"     "classe"
```

```
nVars = ncol(myCleanTrain)
```

There are now a total of **54 variables** available for prediction modelling.

4.Machine Learning / Prediction Modelling

[Refer to the Appendix for Data Exploration Activities and Findings]

In order to predict activity, as indicated by the categorical variable *classe* (factors "A", "B", "C", "D", "E"), we have created several models and chosen the best that gives the highest Accuracy.

The models that have been used are Classification and Regression Tree (CART), Linear Discriminant Analysis (LDA), Boosting and Random Forest. The predictions also use cross-validation to improve the modelling. We will also be performing transformations before modelling the parametric LDA.

With each model, the IN SAMPLE ERROR (Resubstitution Error) using *myCleanTrain* data set and OUT OF SAMPLE ERROR (Generalization Error) using a cleaned *myTest* and calculated and used for finding the best model fit.

The errors have been the least for **Random Forest** prediction for this dataset.

We will describe the prediction and accuracy using Random Forest below.

[Refer to the Appendix for prediction and accuracy using CART, LDA and Boosting]

A 10-fold cross validation has been used to reduce over-fitting duing Random Forest modelling. The splitting of the data set in to a 70:30 training:test is also to detect over-fitting.

Before modelling, let us apply the same cleaning method that we created with *myTrain* dataset, on the *myTest* dataset. The cleaned myTest dataset is needed for the OUT OF SAMPLE ERROR computation.

```
myCleanTest = subset (myTest, new_window == "no")
myCleanTest = myCleanTest [ , naVecs]
myCleanTest = subset (myCleanTest, select = -(nzv))
myCleanTest = subset (myCleanTest, select = -(X:cvtd_timestamp))
```

RANDOM FOREST MODELLING

Random Forest is performed on the cleaned training data, with a cross-validation of 10 folds.

```
fitControl = trainControl (method = "cv", number = 10)
rfFit = train (classe ~ ., data = myCleanTrain, method = "rf", trControl = fitControl, verbose = FALSE)

# Print the Fit
rfFit
```

```
## Random Forest
##
## 13464 samples
##    53 predictor
##     5 classes: 'A', 'B', 'C', 'D', 'E'
##
## No pre-processing
## Resampling: Cross-Validated (10 fold)
##
## Summary of sample sizes: 12118, 12118, 12119, 12116, 12118, 12117, ...
```

```
##
## Resampling results across tuning parameters:
##
##   mtry  Accuracy   Kappa      Accuracy SD  Kappa SD
##    2    0.9945775  0.9931403  0.002952517  0.003735445
##   27    0.9973999  0.9967110  0.001724968  0.002182230
##   53    0.9947256  0.9933273  0.003630689  0.004594744
##
## Accuracy was used to select the optimal model using  the largest value.
## The final value used for the model was mtry = 27.
```

```
# Print the model
rfFit$finalModel
```

```
##
## Call:
##  randomForest(x = x, y = y, mtry = param$mtry, verbose = FALSE)
##                Type of random forest: classification
##                      Number of trees: 500
## No. of variables tried at each split: 27
##
##         OOB estimate of  error rate: 0.19%
## Confusion matrix:
##      A    B    C    D    E  class.error
## A 3828    1    0    0    1 0.0005221932
## B    6 2592    2    1    0 0.0034602076
## C    0    3 2341    1    0 0.0017057569
## D    0    0    6 2206    0 0.0027124774
## E    0    0    0    4 2472 0.0016155089
```

```
# Print Accuracy IN SAMPLE
accuracyIS = confusionMatrix (myCleanTrain$classe, predict (rfFit, myCleanTrain))$overall[1]
accuracyIS
```

```
## Accuracy
##        1
```

```
# Print Accuracy OUT OF SAMPLE
accuracyOS = confusionMatrix (myCleanTest$classe, predict (rfFit, myCleanTest))$overall[1]
accuracyOS
```

```
##  Accuracy
## 0.9963491
```

The Random Forest model yields an **in-sample error of 0%** and an **out-of-sample error of 0.365%**.

IV. Prediction on Original Test Data (Conclusion)

Finally, let us apply the random forest model to predict the human activity for the project's original test data **testing** from *testing.csv*

We will once again apply the same cleaning method to this data.

```
myValidationTest = subset (testing, new_window == "no")
myValidationTest = myValidationTest [ , naVecs]
myValidationTest = subset (myValidationTest, select = -(nzv))
myValidationTest = subset (myValidationTest, select = -(X:cvtd_timestamp))
```

```
pred = predict (rfFit, myValidationTest)
pred
```

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

The predictions for the **Testing** data using random forest modelling are **B, A, B, A, A, E, D, B, A, A, B, C, B, A, E, E, A, B, B, B**

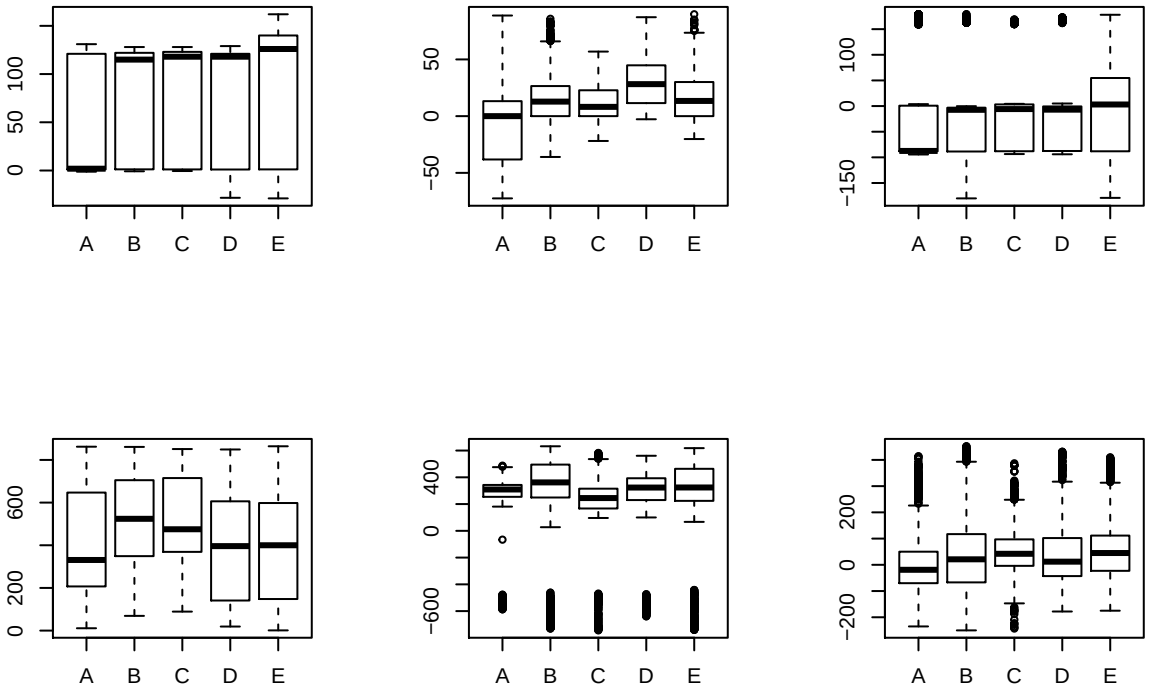
Appendix

A. Data Exploration

In data exploration, we will box plot the variables identified to be important by the non-parametric models only (plotting all 54 variables will be messy and an overkill). Will also plot each of these variable's summary for finer details.

```
par (mfrow = c(2,3))

boxplot (roll_belt ~ classe, data = myCleanTrain)
boxplot (pitch_forearm ~ classe, data = myCleanTrain)
boxplot (yaw_belt ~ classe, data = myCleanTrain)
boxplot (num_window ~ classe, data = myCleanTrain)
boxplot (magnet_dumbbell_y ~ classe, data = myCleanTrain)
boxplot (magnet_dumbbell_z ~ classe, data = myCleanTrain)
```




```
par (mfrow = c(1,1))

summary (myCleanTrain[,c("roll_belt", "pitch_forearm", "yaw_belt")])
```

```
##    roll_belt       pitch_forearm        yaw_belt
##  Min.   :-28.900   Min.   :-72.500   Min.   :-180.00
##  1st Qu.:  1.097   1st Qu.:  0.000   1st Qu.: -88.30
##  Median :113.000   Median :  9.595   Median : -13.10
##  Mean   : 64.360   Mean   : 10.955   Mean   : -10.97
##  3rd Qu.:123.000   3rd Qu.: 28.600   3rd Qu.:  13.43
##  Max.   :162.000   Max.   : 89.800   Max.   : 179.00
```

```
summary (myCleanTrain[,c("num_window", "magnet_dumbbell_y", "magnet_dumbbell_z")])
```

```
##    num_window    magnet_dumbbell_y magnet_dumbbell_z
##  Min.   :  1.0   Min.   :-744      Min.   :-250.00
##  1st Qu.:220.8   1st Qu.: 231      1st Qu.: -46.00
##  Median :424.0   Median : 310      Median :  13.00
##  Mean   :430.1   Mean   : 219      Mean   :  45.84
##  3rd Qu.:643.0   3rd Qu.: 390      3rd Qu.:  94.25
##  Max.   :864.0   Max.   : 632      Max.   : 452.00
```

From the above exploration, we can observe the below about the variables -

roll_belt - Appears very clean and usable in modelling.

pitch_forearm - Appears clean with few outliers for activity B.

yaw_belt - Appears to have outliers in positive direction... Would be a good idea to apply log10 on this variable for parametric modelling. Outliers should not pose a problem for non-parametric modelling.

num_window - Appears very clean and usable in modelling.

magnet_dumbbell_y - - Appears very clean and usable in modelling.

magnet_dumbbell_z - Appears to have heavy outliers and a high spread. Definitely needs to be transformed using log10 for parametric modelling.

We will also check if any of the variables are correlated.

```
#Perform correlation without the prediction variable
indexClasse = which (colnames (myCleanTrain) == "classe")

corMat = abs(round (cor(myCleanTrain[,-indexClasse]), 2))
diag (corMat) = 0
which (corMat > 0.8, arr.ind = TRUE) #print high correlation indices
```

```
##                   row col
## yaw_belt            4   2
## total_accel_belt    5   2
## accel_belt_y       10   2
## accel_belt_z       11   2
## accel_belt_x        9   3
## magnet_belt_x      12   3
## roll_belt           2   4
## roll_belt           2   5
## accel_belt_y       10   5
## accel_belt_z       11   5
## pitch_belt          3   9
## magnet_belt_x      12   9
## roll_belt           2  10
## total_accel_belt    5  10
## accel_belt_z       11  10
## roll_belt           2  11
## total_accel_belt    5  11
## accel_belt_y       10  11
## pitch_belt          3  12
## accel_belt_x        9  12
## gyros_arm_y        20  19
## gyros_arm_x        19  20
## magnet_arm_x       25  22
## accel_arm_x        22  25
## magnet_arm_z       27  26
## magnet_arm_y       26  27
## accel_dumbbell_x   35  29
## accel_dumbbell_z   37  30
## gyros_dumbbell_z   34  32
## gyros_forearm_z    47  32
## gyros_dumbbell_x   32  34
## gyros_forearm_z    47  34
## pitch_dumbbell     29  35
## yaw_dumbbell       30  37
```

```
## gyros_forearm_z   47  46
## gyros_dumbbell_x  32  47
## gyros_dumbbell_z  34  47
## gyros_forearm_y   46  47
```

There does appear to be predictor variables that are correlated. Principal Component Analysis would be required to be performed for parametric modelling.

B. Other Models Explored with their Prediction Accuracy

1. Classification and Regression Tree (CART)

CART is performed on the cleaned training data, with a cross-validation of 10 folds. There was no change in the result when the cross-validation folds were increased to 20.

```
fitControl = trainControl (method = "cv", number = 10)
cartFit = train (classe ~ ., method = "rpart", data = myCleanTrain, trControl = fitControl)

# Print Model
cartFit$finalModel
```

```
## n= 13464
##
## node), split, n, loss, yval, (yprob)
##       * denotes terminal node
##
##  1) root 13464 9634 A (0.28 0.19 0.17 0.16 0.18)
##    2) roll_belt< 129.5 12272 8482 A (0.31 0.21 0.19 0.18 0.11)
##      4) pitch_forearm< -33.95 1072    9 A (0.99 0.0084 0 0 0) *
##      5) pitch_forearm>=-33.95 11200 8473 A (0.24 0.23 0.21 0.2 0.12)
##       10) num_window>=45.5 10689 7962 A (0.26 0.24 0.22 0.2 0.086)
##         20) magnet_dumbbell_y< 439.5 9123 6455 A (0.29 0.19 0.25 0.19 0.083)
##           40) roll_forearm< 123.5 5746 3350 A (0.42 0.19 0.19 0.16 0.042) *
##           41) roll_forearm>=123.5 3377 2202 C (0.081 0.19 0.35 0.23 0.15) *
##         21) magnet_dumbbell_y>=439.5 1566  679 B (0.038 0.57 0.05 0.24 0.1) *
##       11) num_window< 45.5 511  106 E (0 0 0 0.21 0.79) *
##    3) roll_belt>=129.5 1192   40 E (0.034 0 0 0 0.97) *
```

```
# Print Accuracy IN SAMPLE
accuracyIS = confusionMatrix (myCleanTrain$classe, predict (cartFit, myCleanTrain))$overall[1]
accuracyIS
```

```
##  Accuracy
## 0.5256982
```

```
# Print Accuracy OUT OF SAMPLE
accuracyOS = confusionMatrix (myCleanTest$classe, predict (cartFit, myCleanTest))$overall[1]
accuracyOS
```

```
##  Accuracy
## 0.5239917
```

The CART model yields an **in-sample error of 47.4%** and an **out-of-sample error of 47.6%**.

2. BOOSTING

Boosting is performed on the cleaned training data, with a cross-validation of 10 folds.

```
fitControl = trainControl (method = "cv", number = 10)
boostFit = train (classe ~ ., data = myCleanTrain, method = "gbm", trControl = fitControl, verbose = FA

# Print Accuracy IN SAMPLE
accuracyIS = confusionMatrix (myCleanTrain$classe, predict (boostFit, myCleanTrain))$overall[1]
accuracyIS
```

```
##  Accuracy
## 0.9942068
```

```
# Print Accuracy OUT OF SAMPLE
accuracyOS = confusionMatrix (myCleanTest$classe, predict (boostFit, myCleanTest))$overall[1]
accuracyOS
```

```
##  Accuracy
## 0.9874826
```

The BOOSTING model yields an **in-sample error of 0.579%** and an **out-of-sample error of 1.25%**.

Although the out-of-sample error rate is very low, it is slightly more lower for Random Forest model.

3. Linear Discriminant Analysis (LDA)

LDA is performed on the cleaned training data, with a cross-validation of 10 folds. Scaling and centering is performed before the modelling as this is a parametric model.

There was no change in the result when the cross-validation folds were increased to 20. Selecting the variables based on variable importance from the other non-parametric models and applying a logrithmic transformation to the very high spread variables (based on data exploration) also did not improve the prediction accuracy.

```
###Linear Discriminant Analysis
fitControl = trainControl (method = "cv", number = 10)
ldaFit = train (classe ~ ., method = "lda", preprocess = c("center", "scale", "pca"), data = myCleanTra

# Print Accuracy IN SAMPLE
accuracyIS = ldaFit$results$Accuracy
accuracyIS
```

```
## [1] 0.7147225
```

```
# Print Accuracy OUT OF SAMPLE
accuracyOS = confusionMatrix (myCleanTest$classe, predict (ldaFit, myCleanTest))$overall[1]
accuracyOS
```

```
## Accuracy
## 0.706363
```

The LDA model yields an **in-sample error of 28.5%** and an **out-of-sample error of 29.4%**.

C. Data Summary Before and After Cleaning

Below is the summary of the data **before cleaning**.

```
summary (myTrain)
```

```
##        X            user_name    raw_timestamp_part_1 raw_timestamp_part_2
##  Min.   :    2   adelmo  :2749   Min.   :1.322e+09    Min.   :   294
##  1st Qu.: 4909   carlitos:2199   1st Qu.:1.323e+09    1st Qu.:254958
##  Median : 9811   charles :2418   Median :1.323e+09    Median :500340
##  Mean   : 9810   eurico  :2122   Mean   :1.323e+09    Mean   :502510
##  3rd Qu.:14679   jeremy  :2386   3rd Qu.:1.323e+09    3rd Qu.:752385
##  Max.   :19622   pedro   :1863   Max.   :1.323e+09    Max.   :998801
##
##           cvtd_timestamp new_window    num_window      roll_belt
##  28/11/2011 14:14:1033   no :13464   Min.   :  1.0   Min.   :-28.90
##  05/12/2011 11:24:1028   yes:  273   1st Qu.:220.0   1st Qu.:  1.10
##  05/12/2011 11:25:1026               Median :424.0   Median :113.00
##  30/11/2011 17:11:1014               Mean   :430.1   Mean   : 64.44
##  02/12/2011 13:34: 985               3rd Qu.:643.0   3rd Qu.:123.00
##  05/12/2011 14:23: 965               Max.   :864.0   Max.   :162.00
##  (Other)         :7686
##    pitch_belt         yaw_belt       total_accel_belt kurtosis_roll_belt
##  Min.   :-54.700   Min.   :-180.00   Min.   : 0.00             :13464
##  1st Qu.:  1.690   1st Qu.: -88.30   1st Qu.: 3.00    #DIV/0!  :    7
##  Median :  5.280   Median : -13.00   Median :17.00    -1.908453:    2
##  Mean   :  0.231   Mean   : -10.91   Mean   :11.32    -0.025513:    1
##  3rd Qu.: 14.800   3rd Qu.:  13.60   3rd Qu.:18.00    -0.033935:    1
##  Max.   : 60.200   Max.   : 179.00   Max.   :28.00    -0.034743:    1
##                                                       (Other)  :  261
##  kurtosis_picth_belt kurtosis_yaw_belt skewness_roll_belt
##            :13464            :13464             :13464
##  #DIV/0!   :   24     #DIV/0!:  273     #DIV/0!  :    7
##  -0.684748:    3                       0.000000 :    3
##  1.326417 :    3                       0.422463 :    2
##  11.094417:    3                       -0.003095:    1
##  -1.750749:    2                       -0.010002:    1
##  (Other)  :  238                       (Other)  :  259
##  skewness_roll_belt.1 skewness_yaw_belt max_roll_belt     max_picth_belt
##            :13464             :13464     Min.   :-94.300   Min.   : 3.00
##  #DIV/0!   :   24      #DIV/0!:  273     1st Qu.:-88.100   1st Qu.: 5.00
##  -0.189082:    2                        Median : -4.900   Median :18.00
##  -0.475418:    2                        Mean   : -5.412   Mean   :12.85
##  -1.159179:    2                        3rd Qu.: 21.800   3rd Qu.:19.00
##  -1.810464:    2                        Max.   :180.000   Max.   :30.00
##  (Other)  :  241                        NA's   :13464     NA's   :13464
##   max_yaw_belt   min_roll_belt     min_pitch_belt   min_yaw_belt
##          :13464   Min.   :-180.00   Min.   : 0.00          :13464
##  -1.4    :   21   1st Qu.: -88.40   1st Qu.: 3.00   -1.4   :   21
##  -1.2    :   18   Median :  -8.80   Median :16.00   -1.2   :   18
##  -0.9    :   16   Mean   : -10.09   Mean   :10.74   -0.9   :   16
##  -1.1    :   15   3rd Qu.:  12.30   3rd Qu.:17.00   -1.1   :   15
##  -1.3    :   15   Max.   : 173.00   Max.   :23.00   -1.3   :   15
##  (Other):  188   NA's   :13464     NA's   :13464   (Other):  188
```

```
##  amplitude_roll_belt amplitude_pitch_belt amplitude_yaw_belt
##  Min.   :  0.000     Min.   : 0.00               :13464
##  1st Qu.:  0.300     1st Qu.: 1.00        #DIV/0!:    7
##  Median :  1.000     Median : 1.00        0.00   :    8
##  Mean   :  4.675     Mean   : 2.11        0.0000 :  258
##  3rd Qu.:  2.140     3rd Qu.: 2.00
##  Max.   :360.000     Max.   :10.00
##  NA's   :13464       NA's   :13464
##  var_total_accel_belt avg_roll_belt     stddev_roll_belt var_roll_belt
##  Min.   : 0.000       Min.   :-20.900   Min.   : 0.00    Min.   :  0.00
##  1st Qu.: 0.100       1st Qu.:  1.126   1st Qu.: 0.20    1st Qu.:  0.00
##  Median : 0.200       Median :116.300   Median : 0.40    Median :  0.10
##  Mean   : 0.869       Mean   : 68.091   Mean   : 1.21    Mean   :  6.47
##  3rd Qu.: 0.300       3rd Qu.:123.100   3rd Qu.: 0.70    3rd Qu.:  0.50
##  Max.   :11.000       Max.   :157.400   Max.   :14.20    Max.   :200.70
##  NA's   :13464        NA's   :13464     NA's   :13464    NA's   :13464
##  avg_pitch_belt    stddev_pitch_belt var_pitch_belt    avg_yaw_belt
##  Min.   :-51.400   Min.   :0.000     Min.   : 0.000   Min.   :-138.30
##  1st Qu.:  2.000   1st Qu.:0.200     1st Qu.: 0.000   1st Qu.: -88.20
##  Median :  5.300   Median :0.300     Median : 0.100   Median :  -6.60
##  Mean   : -0.187   Mean   :0.592     Mean   : 0.743   Mean   :  -8.18
##  3rd Qu.: 14.200   3rd Qu.:0.700     3rd Qu.: 0.500   3rd Qu.:  18.70
##  Max.   : 28.100   Max.   :4.000     Max.   :16.200   Max.   : 173.50
##  NA's   :13464     NA's   :13464     NA's   :13464    NA's   :13464
##  stddev_yaw_belt    var_yaw_belt       gyros_belt_x
##  Min.   :  0.000   Min.   :    0.00   Min.   :-1.040000
##  1st Qu.:  0.100   1st Qu.:    0.01   1st Qu.:-0.050000
##  Median :  0.300   Median :    0.09   Median : 0.030000
##  Mean   :  1.698   Mean   :  159.37   Mean   :-0.007106
##  3rd Qu.:  0.700   3rd Qu.:    0.48   3rd Qu.: 0.110000
##  Max.   :176.600   Max.   :31183.24   Max.   : 2.220000
##  NA's   :13464     NA's   :13464
##   gyros_belt_y       gyros_belt_z      accel_belt_x       accel_belt_y
##  Min.   :-0.51000   Min.   :-1.3500   Min.   :-120.000   Min.   :-69.00
##  1st Qu.: 0.00000   1st Qu.:-0.2000   1st Qu.: -21.000   1st Qu.:  3.00
##  Median : 0.02000   Median :-0.1000   Median : -15.000   Median : 35.00
##  Mean   : 0.03958   Mean   :-0.1311   Mean   :  -5.506   Mean   : 30.15
##  3rd Qu.: 0.11000   3rd Qu.:-0.0200   3rd Qu.:  -5.000   3rd Qu.: 61.00
##  Max.   : 0.64000   Max.   : 1.6100   Max.   :  85.000   Max.   :164.00
##
##   accel_belt_z     magnet_belt_x    magnet_belt_y   magnet_belt_z
##  Min.   :-269.00   Min.   :-48.00   Min.   :359.0   Min.   :-623.0
##  1st Qu.:-162.00   1st Qu.:  9.00   1st Qu.:582.0   1st Qu.:-375.0
##  Median :-152.00   Median : 34.00   Median :601.0   Median :-319.0
##  Mean   : -72.67   Mean   : 55.64   Mean   :593.8   Mean   :-345.3
##  3rd Qu.:  27.00   3rd Qu.: 60.00   3rd Qu.:610.0   3rd Qu.:-306.0
##  Max.   : 105.00   Max.   :479.00   Max.   :673.0   Max.   : 293.0
##
##     roll_arm         pitch_arm          yaw_arm         total_accel_arm
##  Min.   :-180.00   Min.   :-88.800   Min.   :-180.000   Min.   : 1.00
##  1st Qu.: -31.00   1st Qu.:-26.000   1st Qu.: -42.900   1st Qu.:17.00
##  Median :   0.00   Median :  0.000   Median :   0.000   Median :27.00
##  Mean   :  18.04   Mean   : -4.599   Mean   :  -1.125   Mean   :25.56
##  3rd Qu.:  77.20   3rd Qu.: 11.300   3rd Qu.:  45.300   3rd Qu.:33.00
```

```
##  Max.   : 180.00   Max.   : 88.500   Max.   : 180.000   Max.   :66.00
##
##  var_accel_arm     avg_roll_arm      stddev_roll_arm    var_roll_arm
##  Min.   :  0.00   Min.   :-166.587   Min.   :  0.000   Min.   :    0.000
##  1st Qu.: 11.84   1st Qu.: -41.945   1st Qu.:  1.550   1st Qu.:    2.404
##  Median : 42.02   Median :   0.000   Median :  5.764   Median :   33.222
##  Mean   : 54.83   Mean   :   7.735   Mean   : 10.922   Mean   :  360.392
##  3rd Qu.: 73.34   3rd Qu.:  73.853   3rd Qu.: 14.923   3rd Qu.:  222.707
##  Max.   :331.70   Max.   : 163.333   Max.   :161.964   Max.   :26232.208
##  NA's   :13464    NA's   :13464      NA's   :13464     NA's   :13464
##  avg_pitch_arm     stddev_pitch_arm var_pitch_arm       avg_yaw_arm
##  Min.   :-77.019   Min.   : 0.000   Min.   :   0.000   Min.   :-173.440
##  1st Qu.:-21.752   1st Qu.: 1.270   1st Qu.:   1.613   1st Qu.: -31.638
##  Median :  0.000   Median : 8.027   Median :  64.428   Median :   0.000
##  Mean   : -4.638   Mean   :10.565   Mean   : 205.581   Mean   :  -1.425
##  3rd Qu.:  7.404   3rd Qu.:16.995   3rd Qu.: 288.833   3rd Qu.:  36.115
##  Max.   : 75.659   Max.   :43.412   Max.   :1884.565   Max.   : 150.458
##  NA's   :13464     NA's   :13464    NA's   :13464      NA's   :13464
##  stddev_yaw_arm    var_yaw_arm         gyros_arm_x        gyros_arm_y
##  Min.   :  0.00   Min.   :    0.000   Min.   :-6.37000   Min.   :-3.4000
##  1st Qu.:  2.12   1st Qu.:    4.494   1st Qu.:-1.32000   1st Qu.:-0.8000
##  Median : 16.84   Median :  283.704   Median : 0.08000   Median :-0.2600
##  Mean   : 21.64   Mean   :  946.977   Mean   : 0.04806   Mean   :-0.2587
##  3rd Qu.: 36.26   3rd Qu.: 1314.890   3rd Qu.: 1.59000   3rd Qu.: 0.1400
##  Max.   :158.08   Max.   :24988.953   Max.   : 4.87000   Max.   : 2.8400
##  NA's   :13464    NA's   :13464
##   gyros_arm_z       accel_arm_x       accel_arm_y       accel_arm_z
##  Min.   :-2.3300   Min.   :-383.00   Min.   :-318.00   Min.   :-636.00
##  1st Qu.:-0.0700   1st Qu.:-241.00   1st Qu.: -54.00   1st Qu.:-144.00
##  Median : 0.2300   Median : -41.00   Median :  14.00   Median : -46.00
##  Mean   : 0.2714   Mean   : -58.62   Mean   :  32.33   Mean   : -71.51
##  3rd Qu.: 0.7200   3rd Qu.:  84.00   3rd Qu.: 138.00   3rd Qu.:  23.00
##  Max.   : 3.0200   Max.   : 437.00   Max.   : 308.00   Max.   : 292.00
##
##   magnet_arm_x     magnet_arm_y     magnet_arm_z    kurtosis_roll_arm
##  Min.   :-584.0   Min.   :-392.0   Min.   :-597.0           :13464
##  1st Qu.:-296.0   1st Qu.: -10.0   1st Qu.: 124.0   #DIV/0! :   52
##  Median : 294.0   Median : 200.0   Median : 443.0   -0.02438:    1
##  Mean   : 194.3   Mean   : 155.9   Mean   : 304.5   -0.05051:    1
##  3rd Qu.: 639.0   3rd Qu.: 322.0   3rd Qu.: 545.0   -0.08050:    1
##  Max.   : 782.0   Max.   : 583.0   Max.   : 694.0   -0.11035:    1
##                                                     (Other) :  217
##  kurtosis_picth_arm kurtosis_yaw_arm skewness_roll_arm skewness_pitch_arm
##          :13464             :13464           :13464            :13464
##  #DIV/0! :   54     #DIV/0! :    8   #DIV/0! :   52    #DIV/0! :   54
##  -0.00484:    1     0.55844 :    2   -0.00051:    1    -0.01185:    1
##  -0.01311:    1     -0.01548:    1   -0.01884:    1    -0.01247:    1
##  -0.10385:    1     -0.02101:    1   -0.03359:    1    -0.02063:    1
##  -0.11279:    1     -0.04059:    1   -0.03484:    1    -0.02986:    1
##  (Other) :  215     (Other) :  260   (Other) :  217    (Other) :  215
##  skewness_yaw_arm  max_roll_arm    max_picth_arm      max_yaw_arm
##          :13464   Min.   :-72.30   Min.   :-173.00   Min.   : 4.0
##  #DIV/0! :    8   1st Qu.:  0.00   1st Qu.:  -5.30   1st Qu.:29.0
##  -0.00311:    1   Median :  6.10   Median :  17.40   Median :34.0
```

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##  -0.00562:    1   Mean   : 12.01   Mean   :  31.59   Mean   :35.5
##  -0.01697:    1   3rd Qu.: 24.70   3rd Qu.:  91.90   3rd Qu.:42.0
##  -0.03455:    1   Max.   : 85.50   Max.   : 180.00   Max.   :62.0
##  (Other) :  261   NA's   :13464    NA's   :13464     NA's   :13464
##   min_roll_arm    min_pitch_arm     min_yaw_arm    amplitude_roll_arm
##  Min.   :-89.10   Min.   :-179.0   Min.   : 2.00   Min.   :  0.00
##  1st Qu.:-41.90   1st Qu.: -71.1   1st Qu.: 8.00   1st Qu.:  4.30
##  Median :-22.90   Median : -33.6   Median :13.00   Median : 28.31
##  Mean   :-20.93   Mean   : -37.0   Mean   :14.46   Mean   : 32.94
##  3rd Qu.:  0.00   3rd Qu.:   0.0   3rd Qu.:19.00   3rd Qu.: 52.70
##  Max.   : 66.40   Max.   : 140.0   Max.   :38.00   Max.   :119.50
##  NA's   :13464    NA's   :13464    NA's   :13464   NA's   :13464
##  amplitude_pitch_arm amplitude_yaw_arm roll_dumbbell     pitch_dumbbell
##  Min.   :  0.00      Min.   : 0.00     Min.   :-153.71   Min.   :-148.50
##  1st Qu.:  9.00      1st Qu.:13.00     1st Qu.: -18.60   1st Qu.: -40.94
##  Median : 55.43      Median :22.00     Median :  48.35   Median : -21.01
##  Mean   : 68.59      Mean   :21.04     Mean   :  23.67   Mean   : -10.90
##  3rd Qu.:115.30      3rd Qu.:28.00     3rd Qu.:  67.46   3rd Qu.:  17.22
##  Max.   :359.00      Max.   :52.00     Max.   : 153.55   Max.   : 149.40
##  NA's   :13464       NA's   :13464
##   yaw_dumbbell      kurtosis_roll_dumbbell kurtosis_picth_dumbbell
##  Min.   :-150.871          :13464                 :13464
##  1st Qu.: -77.731   -0.2583:    2          -0.0163:    1
##  Median :  -3.911   -0.5855:    2          -0.0233:    1
##  Mean   :   1.520   #DIV/0!:    2          -0.0308:    1
##  3rd Qu.:  79.603   -0.0035:    1          -0.0393:    1
##  Max.   : 154.952   -0.0073:    1          -0.0402:    1
##                     (Other):  265          (Other):  268
##  kurtosis_yaw_dumbbell skewness_roll_dumbbell skewness_pitch_dumbbell
##         :13464                :13464                 :13464
##  #DIV/0!:  273         -0.9324:    2          -0.7036:    2
##                        #DIV/0!:    2          0.1090 :    2
##                        -0.0430:    1          -0.0166:    1
##                        -0.0552:    1          -0.0452:    1
##                        -0.0649:    1          -0.0458:    1
##                        (Other):  266          (Other):  266
##  skewness_yaw_dumbbell max_roll_dumbbell max_picth_dumbbell
##         :13464         Min.   :-70.100   Min.   :-112.90
##  #DIV/0!:  273         1st Qu.:-30.100   1st Qu.: -68.30
##                        Median :  2.800   Median :  31.10
##                        Mean   :  9.578   Mean   :  26.64
##                        3rd Qu.: 45.800   3rd Qu.: 128.40
##                        Max.   :137.000   Max.   : 155.00
##                        NA's   :13464     NA's   :13464
##  max_yaw_dumbbell min_roll_dumbbell min_pitch_dumbbell min_yaw_dumbbell
##         :13464    Min.   :-128.10   Min.   :-147.00           :13464
##  -0.8   :   13    1st Qu.: -59.50   1st Qu.: -94.20    -0.8   :   13
##  0.2    :   12    Median : -43.80   Median : -69.80    0.2    :   12
##  -0.5   :   11    Mean   : -41.19   Mean   : -35.12    -0.5   :   11
##  -0.6   :   11    3rd Qu.: -27.50   3rd Qu.:  14.70    -0.6   :   11
##  0.9    :   11    Max.   :  34.50   Max.   : 120.90    0.9    :   11
##  (Other):  215    NA's   :13464     NA's   :13464      (Other):  215
##  amplitude_roll_dumbbell amplitude_pitch_dumbbell amplitude_yaw_dumbbell
##  Min.   :  0.00          Min.   :  0.00                  :13464
```

```
##  1st Qu.: 15.29          1st Qu.: 17.17          #DIV/0!:    2
##  Median : 31.21          Median : 37.99          0.00   :  271
##  Mean   : 50.77          Mean   : 61.76
##  3rd Qu.: 72.72          3rd Qu.: 87.95
##  Max.   :233.19          Max.   :273.59
##  NA's   :13464           NA's   :13464
##  total_accel_dumbbell var_accel_dumbbell avg_roll_dumbbell
##  Min.   : 0.00        Min.   :  0.000    Min.   :-128.96
##  1st Qu.: 5.00        1st Qu.:  0.361    1st Qu.: -24.45
##  Median :11.00        Median :  0.922    Median :  47.19
##  Mean   :13.79        Mean   :  4.158    Mean   :  20.55
##  3rd Qu.:20.00        3rd Qu.:  2.719    3rd Qu.:  62.34
##  Max.   :58.00        Max.   :230.428    Max.   : 125.99
##                       NA's   :13464      NA's   :13464
##  stddev_roll_dumbbell var_roll_dumbbell  avg_pitch_dumbbell
##  Min.   :  0.000      Min.   :    0.00   Min.   :-70.73
##  1st Qu.:  4.585      1st Qu.:   21.02   1st Qu.:-43.76
##  Median : 10.686      Median :  114.19   Median :-23.00
##  Mean   : 19.309      Mean   :  905.81   Mean   :-15.62
##  3rd Qu.: 23.199      3rd Qu.:  538.17   3rd Qu.: 10.88
##  Max.   :107.761      Max.   :11612.41   Max.   : 94.28
##  NA's   :13464        NA's   :13464      NA's   :13464
##  stddev_pitch_dumbbell var_pitch_dumbbell avg_yaw_dumbbell
##  Min.   : 0.000        Min.   :   0.00    Min.   :-117.950
##  1st Qu.: 3.556        1st Qu.:  12.65    1st Qu.: -77.164
##  Median : 7.324        Median :  53.64    Median : -10.068
##  Mean   :12.057        Mean   : 303.74    Mean   :  -3.942
##  3rd Qu.:17.148        3rd Qu.: 294.06    3rd Qu.:  66.029
##  Max.   :82.680        Max.   :6836.02    Max.   : 134.905
##  NA's   :13464         NA's   :13464      NA's   :13464
##  stddev_yaw_dumbbell var_yaw_dumbbell  gyros_dumbbell_x
##  Min.   : 0.000      Min.   :   0.00   Min.   :-204.0000
##  1st Qu.: 3.902      1st Qu.:  15.23   1st Qu.:  -0.0300
##  Median : 8.719      Median :  76.03   Median :   0.1400
##  Mean   :15.476      Mean   : 522.62   Mean   :   0.1579
##  3rd Qu.:21.705      3rd Qu.: 471.12   3rd Qu.:   0.3500
##  Max.   :99.563      Max.   :9912.85   Max.   :   2.2000
##  NA's   :13464       NA's   :13464
##  gyros_dumbbell_y   gyros_dumbbell_z   accel_dumbbell_x accel_dumbbell_y
##  Min.   :-2.10000   Min.   : -1.9500   Min.   :-419.0   Min.   :-179.00
##  1st Qu.:-0.14000   1st Qu.: -0.3100   1st Qu.: -50.0   1st Qu.:  -9.00
##  Median : 0.03000   Median : -0.1300   Median :  -9.0   Median :  43.00
##  Mean   : 0.04766   Mean   : -0.1234   Mean   : -28.6   Mean   :  52.83
##  3rd Qu.: 0.21000   3rd Qu.:  0.0300   3rd Qu.:  11.0   3rd Qu.: 111.00
##  Max.   :52.00000   Max.   :317.0000   Max.   : 235.0   Max.   : 315.00
##
##  accel_dumbbell_z  magnet_dumbbell_x magnet_dumbbell_y magnet_dumbbell_z
##  Min.   :-334.00   Min.   :-643.0    Min.   :-744.0    Min.   :-250.00
##  1st Qu.:-142.00   1st Qu.:-535.0    1st Qu.: 231.0    1st Qu.: -46.00
##  Median :  -1.00   Median :-479.0    Median : 310.0    Median :  13.00
##  Mean   : -38.82   Mean   :-325.5    Mean   : 219.1    Mean   :  45.65
##  3rd Qu.:  39.00   3rd Qu.:-295.0    3rd Qu.: 390.0    3rd Qu.:  94.00
##  Max.   : 318.00   Max.   : 584.0    Max.   : 632.0    Max.   : 452.00
##
```

```
##   roll_forearm     pitch_forearm     yaw_forearm
##  Min.   :-180.00   Min.   :-72.50   Min.   :-180.00
##  1st Qu.:  -0.67   1st Qu.:  0.00   1st Qu.: -69.10
##  Median :  21.00   Median :  9.60   Median :   0.00
##  Mean   :  33.98   Mean   : 10.97   Mean   :  18.92
##  3rd Qu.: 140.00   3rd Qu.: 28.70   3rd Qu.: 110.00
##  Max.   : 180.00   Max.   : 89.80   Max.   : 180.00
##
##  kurtosis_roll_forearm kurtosis_picth_forearm kurtosis_yaw_forearm
##         :13464                :13464                 :13464
##  #DIV/0!:   58         #DIV/0!:   59          #DIV/0!:  273
##  -0.8079:    2         -0.0073:    1
##  -0.0227:    1         -0.0442:    1
##  -0.0567:    1         -0.0489:    1
##  -0.0781:    1         -0.0523:    1
##  (Other):  210         (Other):  210
##  skewness_roll_forearm skewness_pitch_forearm skewness_yaw_forearm
##         :13464                :13464                 :13464
##  #DIV/0!:   58         #DIV/0!:   59          #DIV/0!:  273
##  -0.1912:    2         0.0000 :    3
##  -0.0004:    1         -0.6992:    2
##  -0.0013:    1         -0.0113:    1
##  -0.0063:    1         -0.0405:    1
##  (Other):  210         (Other):  207
##  max_roll_forearm max_picth_forearm max_yaw_forearm min_roll_forearm
##  Min.   :-66.60   Min.   :-151.0          :13464   Min.   :-72.50
##  1st Qu.:  0.00   1st Qu.:   0.0    #DIV/0!:   58   1st Qu.: -7.80
##  Median : 28.30   Median : 113.0    -1.3   :   26   Median :  0.00
##  Mean   : 24.01   Mean   :  81.2    -1.2   :   19   Mean   : -1.64
##  3rd Qu.: 46.70   3rd Qu.: 175.0    -1.5   :   17   3rd Qu.: 11.10
##  Max.   : 87.90   Max.   : 180.0    -1.6   :   16   Max.   : 60.40
##  NA's   :13464    NA's   :13464     (Other):  137   NA's   :13464
##  min_pitch_forearm min_yaw_forearm amplitude_roll_forearm
##  Min.   :-180.00          :13464   Min.   :  0.00
##  1st Qu.:-175.00   #DIV/0!:   58   1st Qu.:  1.00
##  Median : -57.90   -1.3   :   26   Median : 19.42
##  Mean   : -56.87   -1.2   :   19   Mean   : 25.65
##  3rd Qu.:   0.00   -1.5   :   17   3rd Qu.: 39.90
##  Max.   : 167.00   -1.6   :   16   Max.   :126.00
##  NA's   :13464     (Other):  137   NA's   :13464
##  amplitude_pitch_forearm amplitude_yaw_forearm total_accel_forearm
##  Min.   :  0.0                   :13464         Min.   :  0.00
##  1st Qu.:  1.3           #DIV/0!:   58         1st Qu.: 29.00
##  Median : 82.6           0.00   :  215         Median : 36.00
##  Mean   :138.1                                 Mean   : 34.75
##  3rd Qu.:350.0                                 3rd Qu.: 41.00
##  Max.   :360.0                                 Max.   :108.00
##  NA's   :13464
##  var_accel_forearm avg_roll_forearm  stddev_roll_forearm
##  Min.   :  0.000   Min.   :-177.23   Min.   :  0.000
##  1st Qu.:  6.107   1st Qu.:   0.00   1st Qu.:  0.403
##  Median : 22.633   Median :  11.54   Median :  8.102
##  Mean   : 32.033   Mean   :  34.74   Mean   : 40.012
##  3rd Qu.: 48.282   3rd Qu.: 114.11   3rd Qu.: 81.102
```

```
##  Max.   :172.606   Max.   : 177.26   Max.   :179.171
##  NA's   :13464     NA's   :13464     NA's   :13464
##  var_roll_forearm   avg_pitch_forearm stddev_pitch_forearm
##  Min.   :    0.00   Min.   :-68.17    Min.   : 0.000
##  1st Qu.:    0.16   1st Qu.:  0.00    1st Qu.: 0.300
##  Median :   65.64   Median : 11.34    Median : 5.976
##  Mean   : 4959.70   Mean   : 10.72    Mean   : 8.289
##  3rd Qu.: 6577.60   3rd Qu.: 27.81    3rd Qu.:12.877
##  Max.   :32102.24   Max.   : 70.15    Max.   :47.745
##  NA's   :13464      NA's   :13464     NA's   :13464
##  var_pitch_forearm avg_yaw_forearm   stddev_yaw_forearm var_yaw_forearm
##  Min.   :   0.00   Min.   :-151.45   Min.   :  0.000    Min.   :    0.00
##  1st Qu.:   0.09   1st Qu.: -25.05   1st Qu.:  0.505    1st Qu.:    0.25
##  Median :  35.72   Median :   0.00   Median : 24.005    Median :  576.24
##  Mean   : 152.33   Mean   :  19.06   Mean   : 44.479    Mean   : 4638.78
##  3rd Qu.: 165.83   3rd Qu.:  85.97   3rd Qu.: 81.945    3rd Qu.: 6714.96
##  Max.   :2279.62   Max.   : 169.24   Max.   :197.508    Max.   :39009.33
##  NA's   :13464     NA's   :13464     NA's   :13464      NA's   :13464
##  gyros_forearm_x    gyros_forearm_y     gyros_forearm_z
##  Min.   :-22.0000   Min.   : -7.02000   Min.   : -7.9400
##  1st Qu.: -0.2200   1st Qu.: -1.48000   1st Qu.: -0.1800
##  Median :  0.0500   Median :  0.03000   Median :  0.0800
##  Mean   :  0.1596   Mean   :  0.08152   Mean   :  0.1557
##  3rd Qu.:  0.5800   3rd Qu.:  1.64000   3rd Qu.:  0.4900
##  Max.   :  3.9700   Max.   :311.00000   Max.   :231.0000
##
##  accel_forearm_x   accel_forearm_y  accel_forearm_z   magnet_forearm_x
##  Min.   :-498.00   Min.   :-632.0   Min.   :-410.00   Min.   :-1280.0
##  1st Qu.:-179.00   1st Qu.:  54.0   1st Qu.:-183.00   1st Qu.: -617.0
##  Median : -57.00   Median : 201.0   Median : -42.00   Median : -383.0
##  Mean   : -62.22   Mean   : 163.5   Mean   : -56.63   Mean   : -314.7
##  3rd Qu.:  75.00   3rd Qu.: 312.0   3rd Qu.:  25.00   3rd Qu.:  -77.0
##  Max.   : 389.00   Max.   : 923.0   Max.   : 287.00   Max.   :  672.0
##
##  magnet_forearm_y magnet_forearm_z classe
##  Min.   :-896.0   Min.   :-966.0   A:3906
##  1st Qu.:  -3.0   1st Qu.: 194.0   B:2658
##  Median : 587.0   Median : 511.0   C:2396
##  Mean   : 375.8   Mean   : 395.6   D:2252
##  3rd Qu.: 736.0   3rd Qu.: 652.0   E:2525
##  Max.   :1480.0   Max.   :1090.0
##
```

```
head (myTrain, 10)
```

```
##     X user_name raw_timestamp_part_1 raw_timestamp_part_2   cvtd_timestamp
## 2   2  carlitos           1323084231               808298 05/12/2011 11:23
## 3   3  carlitos           1323084231               820366 05/12/2011 11:23
## 4   4  carlitos           1323084232               120339 05/12/2011 11:23
## 5   5  carlitos           1323084232               196328 05/12/2011 11:23
## 6   6  carlitos           1323084232               304277 05/12/2011 11:23
## 7   7  carlitos           1323084232               368296 05/12/2011 11:23
## 8   8  carlitos           1323084232               440390 05/12/2011 11:23
## 12 12  carlitos           1323084232               528316 05/12/2011 11:23
```

```
## 13 13  carlitos           1323084232              560359 05/12/2011 11:23
## 14 14  carlitos           1323084232              576390 05/12/2011 11:23
##    new_window num_window roll_belt pitch_belt yaw_belt total_accel_belt
## 2          no         11      1.41       8.07    -94.4                3
## 3          no         11      1.42       8.07    -94.4                3
## 4          no         12      1.48       8.05    -94.4                3
## 5          no         12      1.48       8.07    -94.4                3
## 6          no         12      1.45       8.06    -94.4                3
## 7          no         12      1.42       8.09    -94.4                3
## 8          no         12      1.42       8.13    -94.4                3
## 12         no         12      1.43       8.18    -94.4                3
## 13         no         12      1.42       8.20    -94.4                3
## 14         no         12      1.42       8.21    -94.4                3
##    kurtosis_roll_belt kurtosis_picth_belt kurtosis_yaw_belt
## 2
## 3
## 4
## 5
## 6
## 7
## 8
## 12
## 13
## 14
##    skewness_roll_belt skewness_roll_belt.1 skewness_yaw_belt max_roll_belt
## 2                                                                       NA
## 3                                                                       NA
## 4                                                                       NA
## 5                                                                       NA
## 6                                                                       NA
## 7                                                                       NA
## 8                                                                       NA
## 12                                                                      NA
## 13                                                                      NA
## 14                                                                      NA
##    max_picth_belt max_yaw_belt min_roll_belt min_pitch_belt min_yaw_belt
## 2              NA                         NA             NA
## 3              NA                         NA             NA
## 4              NA                         NA             NA
## 5              NA                         NA             NA
## 6              NA                         NA             NA
## 7              NA                         NA             NA
## 8              NA                         NA             NA
## 12             NA                         NA             NA
## 13             NA                         NA             NA
## 14             NA                         NA             NA
##    amplitude_roll_belt amplitude_pitch_belt amplitude_yaw_belt
## 2                   NA                   NA
## 3                   NA                   NA
## 4                   NA                   NA
## 5                   NA                   NA
## 6                   NA                   NA
## 7                   NA                   NA
## 8                   NA                   NA
```

```
## 12                  NA                   NA
## 13                  NA                   NA
## 14                  NA                   NA
##    var_total_accel_belt avg_roll_belt stddev_roll_belt var_roll_belt
## 2                    NA            NA                NA            NA
## 3                    NA            NA                NA            NA
## 4                    NA            NA                NA            NA
## 5                    NA            NA                NA            NA
## 6                    NA            NA                NA            NA
## 7                    NA            NA                NA            NA
## 8                    NA            NA                NA            NA
## 12                   NA            NA                NA            NA
## 13                   NA            NA                NA            NA
## 14                   NA            NA                NA            NA
##    avg_pitch_belt stddev_pitch_belt var_pitch_belt avg_yaw_belt
## 2              NA                NA             NA           NA
## 3              NA                NA             NA           NA
## 4              NA                NA             NA           NA
## 5              NA                NA             NA           NA
## 6              NA                NA             NA           NA
## 7              NA                NA             NA           NA
## 8              NA                NA             NA           NA
## 12             NA                NA             NA           NA
## 13             NA                NA             NA           NA
## 14             NA                NA             NA           NA
##    stddev_yaw_belt var_yaw_belt gyros_belt_x gyros_belt_y gyros_belt_z
## 2               NA           NA         0.02         0.00        -0.02
## 3               NA           NA         0.00         0.00        -0.02
## 4               NA           NA         0.02         0.00        -0.03
## 5               NA           NA         0.02         0.02        -0.02
## 6               NA           NA         0.02         0.00        -0.02
## 7               NA           NA         0.02         0.00        -0.02
## 8               NA           NA         0.02         0.00        -0.02
## 12              NA           NA         0.02         0.00        -0.02
## 13              NA           NA         0.02         0.00         0.00
## 14              NA           NA         0.02         0.00        -0.02
##    accel_belt_x accel_belt_y accel_belt_z magnet_belt_x magnet_belt_y
## 2           -22            4           22            -7           608
## 3           -20            5           23            -2           600
## 4           -22            3           21            -6           604
## 5           -21            2           24            -6           600
## 6           -21            4           21             0           603
## 7           -22            3           21            -4           599
## 8           -22            4           21            -2           603
## 12          -22            2           23            -2           602
## 13          -22            4           21            -3           606
## 14          -22            4           21            -8           598
##    magnet_belt_z roll_arm pitch_arm yaw_arm total_accel_arm var_accel_arm
## 2           -311     -128      22.5    -161              34            NA
## 3           -305     -128      22.5    -161              34            NA
## 4           -310     -128      22.1    -161              34            NA
## 5           -302     -128      22.1    -161              34            NA
## 6           -312     -128      22.0    -161              34            NA
## 7           -311     -128      21.9    -161              34            NA
```

```
## 8           -313     -128      21.8    -161              34            NA
## 12          -319     -128      21.5    -161              34            NA
## 13          -309     -128      21.4    -161              34            NA
## 14          -310     -128      21.4    -161              34            NA
##    avg_roll_arm stddev_roll_arm var_roll_arm avg_pitch_arm
## 2            NA              NA           NA            NA
## 3            NA              NA           NA            NA
## 4            NA              NA           NA            NA
## 5            NA              NA           NA            NA
## 6            NA              NA           NA            NA
## 7            NA              NA           NA            NA
## 8            NA              NA           NA            NA
## 12           NA              NA           NA            NA
## 13           NA              NA           NA            NA
## 14           NA              NA           NA            NA
##    stddev_pitch_arm var_pitch_arm avg_yaw_arm stddev_yaw_arm var_yaw_arm
## 2                NA            NA          NA             NA          NA
## 3                NA            NA          NA             NA          NA
## 4                NA            NA          NA             NA          NA
## 5                NA            NA          NA             NA          NA
## 6                NA            NA          NA             NA          NA
## 7                NA            NA          NA             NA          NA
## 8                NA            NA          NA             NA          NA
## 12               NA            NA          NA             NA          NA
## 13               NA            NA          NA             NA          NA
## 14               NA            NA          NA             NA          NA
##    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
## 8         0.02       -0.02        0.00        -289         111        -124
## 12        0.02       -0.03        0.00        -288         111        -123
## 13        0.02       -0.02       -0.02        -287         111        -124
## 14        0.02        0.00       -0.03        -288         111        -124
##    magnet_arm_x magnet_arm_y magnet_arm_z kurtosis_roll_arm
## 2          -369          337          513
## 3          -368          344          513
## 4          -372          344          512
## 5          -374          337          506
## 6          -369          342          513
## 7          -373          336          509
## 8          -372          338          510
## 12         -363          343          520
## 13         -372          338          509
## 14         -371          331          523
##    kurtosis_picth_arm kurtosis_yaw_arm skewness_roll_arm
## 2
## 3
## 4
## 5
## 6
```

```
## 7
## 8
## 12
## 13
## 14
##    skewness_pitch_arm skewness_yaw_arm max_roll_arm max_picth_arm
## 2                                              NA            NA
## 3                                              NA            NA
## 4                                              NA            NA
## 5                                              NA            NA
## 6                                              NA            NA
## 7                                              NA            NA
## 8                                              NA            NA
## 12                                             NA            NA
## 13                                             NA            NA
## 14                                             NA            NA
##    max_yaw_arm min_roll_arm min_pitch_arm min_yaw_arm amplitude_roll_arm
## 2           NA           NA            NA          NA                 NA
## 3           NA           NA            NA          NA                 NA
## 4           NA           NA            NA          NA                 NA
## 5           NA           NA            NA          NA                 NA
## 6           NA           NA            NA          NA                 NA
## 7           NA           NA            NA          NA                 NA
## 8           NA           NA            NA          NA                 NA
## 12          NA           NA            NA          NA                 NA
## 13          NA           NA            NA          NA                 NA
## 14          NA           NA            NA          NA                 NA
##    amplitude_pitch_arm amplitude_yaw_arm roll_dumbbell pitch_dumbbell
## 2                   NA                NA      13.13074      -70.63751
## 3                   NA                NA      12.85075      -70.27812
## 4                   NA                NA      13.43120      -70.39379
## 5                   NA                NA      13.37872      -70.42856
## 6                   NA                NA      13.38246      -70.81759
## 7                   NA                NA      13.12695      -70.24757
## 8                   NA                NA      12.75083      -70.34768
## 12                  NA                NA      13.10321      -70.45975
## 13                  NA                NA      13.38246      -70.81759
## 14                  NA                NA      13.41048      -70.99594
##    yaw_dumbbell kurtosis_roll_dumbbell kurtosis_picth_dumbbell
## 2     -84.71065
## 3     -85.14078
## 4     -84.87363
## 5     -84.85306
## 6     -84.46500
## 7     -85.09961
## 8     -85.09708
## 12    -84.89472
## 13    -84.46500
## 14    -84.28005
##    kurtosis_yaw_dumbbell skewness_roll_dumbbell skewness_pitch_dumbbell
## 2
## 3
## 4
## 5
```

```
## 6
## 7
## 8
## 12
## 13
## 14
##    skewness_yaw_dumbbell max_roll_dumbbell max_picth_dumbbell
## 2                                       NA                  NA
## 3                                       NA                  NA
## 4                                       NA                  NA
## 5                                       NA                  NA
## 6                                       NA                  NA
## 7                                       NA                  NA
## 8                                       NA                  NA
## 12                                      NA                  NA
## 13                                      NA                  NA
## 14                                      NA                  NA
##    max_yaw_dumbbell min_roll_dumbbell min_pitch_dumbbell min_yaw_dumbbell
## 2                                 NA                  NA
## 3                                 NA                  NA
## 4                                 NA                  NA
## 5                                 NA                  NA
## 6                                 NA                  NA
## 7                                 NA                  NA
## 8                                 NA                  NA
## 12                                NA                  NA
## 13                                NA                  NA
## 14                                NA                  NA
##    amplitude_roll_dumbbell amplitude_pitch_dumbbell amplitude_yaw_dumbbell
## 2                       NA                       NA
## 3                       NA                       NA
## 4                       NA                       NA
## 5                       NA                       NA
## 6                       NA                       NA
## 7                       NA                       NA
## 8                       NA                       NA
## 12                      NA                       NA
## 13                      NA                       NA
## 14                      NA                       NA
##    total_accel_dumbbell var_accel_dumbbell avg_roll_dumbbell
## 2                    37                 NA                NA
## 3                    37                 NA                NA
## 4                    37                 NA                NA
## 5                    37                 NA                NA
## 6                    37                 NA                NA
## 7                    37                 NA                NA
## 8                    37                 NA                NA
## 12                   37                 NA                NA
## 13                   37                 NA                NA
## 14                   37                 NA                NA
##    stddev_roll_dumbbell var_roll_dumbbell avg_pitch_dumbbell
## 2                    NA                NA                 NA
## 3                    NA                NA                 NA
## 4                    NA                NA                 NA
```

```
## 5                    NA                NA                 NA
## 6                    NA                NA                 NA
## 7                    NA                NA                 NA
## 8                    NA                NA                 NA
## 12                   NA                NA                 NA
## 13                   NA                NA                 NA
## 14                   NA                NA                 NA
##    stddev_pitch_dumbbell var_pitch_dumbbell avg_yaw_dumbbell
## 2                     NA                NA               NA
## 3                     NA                NA               NA
## 4                     NA                NA               NA
## 5                     NA                NA               NA
## 6                     NA                NA               NA
## 7                     NA                NA               NA
## 8                     NA                NA               NA
## 12                    NA                NA               NA
## 13                    NA                NA               NA
## 14                    NA                NA               NA
##    stddev_yaw_dumbbell var_yaw_dumbbell gyros_dumbbell_x gyros_dumbbell_y
## 2                   NA               NA             0.00            -0.02
## 3                   NA               NA             0.00            -0.02
## 4                   NA               NA             0.00            -0.02
## 5                   NA               NA             0.00            -0.02
## 6                   NA               NA             0.00            -0.02
## 7                   NA               NA             0.00            -0.02
## 8                   NA               NA             0.00            -0.02
## 12                  NA               NA             0.00            -0.02
## 13                  NA               NA             0.00            -0.02
## 14                  NA               NA             0.02            -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
## 8              0.00             -234               46             -272
## 12             0.00             -233               47             -270
## 13            -0.02             -234               48             -269
## 14            -0.02             -234               48             -268
##    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
## 8               -555               300               -74         27.8
## 12              -554               291               -65         27.5
## 13              -552               302               -69         27.2
## 14              -554               295               -68         27.2
##    pitch_forearm yaw_forearm kurtosis_roll_forearm kurtosis_picth_forearm
## 2          -63.9        -153
## 3          -63.9        -152
```

```
## 4          -63.9        -152
## 5          -63.9        -152
## 6          -63.9        -152
## 7          -63.9        -152
## 8          -63.8        -152
## 12         -63.8        -152
## 13         -63.9        -151
## 14         -63.9        -151
##    kurtosis_yaw_forearm skewness_roll_forearm skewness_pitch_forearm
## 2
## 3
## 4
## 5
## 6
## 7
## 8
## 12
## 13
## 14
##    skewness_yaw_forearm max_roll_forearm max_picth_forearm max_yaw_forearm
## 2                                    NA                NA
## 3                                    NA                NA
## 4                                    NA                NA
## 5                                    NA                NA
## 6                                    NA                NA
## 7                                    NA                NA
## 8                                    NA                NA
## 12                                   NA                NA
## 13                                   NA                NA
## 14                                   NA                NA
##    min_roll_forearm min_pitch_forearm min_yaw_forearm
## 2                NA                NA
## 3                NA                NA
## 4                NA                NA
## 5                NA                NA
## 6                NA                NA
## 7                NA                NA
## 8                NA                NA
## 12               NA                NA
## 13               NA                NA
## 14               NA                NA
##    amplitude_roll_forearm amplitude_pitch_forearm amplitude_yaw_forearm
## 2                      NA                     NA
## 3                      NA                     NA
## 4                      NA                     NA
## 5                      NA                     NA
## 6                      NA                     NA
## 7                      NA                     NA
## 8                      NA                     NA
## 12                     NA                     NA
## 13                     NA                     NA
## 14                     NA                     NA
##    total_accel_forearm var_accel_forearm avg_roll_forearm
## 2                   36                NA               NA
```

```
## 3                   36                NA               NA
## 4                   36                NA               NA
## 5                   36                NA               NA
## 6                   36                NA               NA
## 7                   36                NA               NA
## 8                   36                NA               NA
## 12                  36                NA               NA
## 13                  36                NA               NA
## 14                  36                NA               NA
##    stddev_roll_forearm var_roll_forearm avg_pitch_forearm
## 2                   NA               NA                NA
## 3                   NA               NA                NA
## 4                   NA               NA                NA
## 5                   NA               NA                NA
## 6                   NA               NA                NA
## 7                   NA               NA                NA
## 8                   NA               NA                NA
## 12                  NA               NA                NA
## 13                  NA               NA                NA
## 14                  NA               NA                NA
##    stddev_pitch_forearm var_pitch_forearm avg_yaw_forearm
## 2                    NA                NA              NA
## 3                    NA                NA              NA
## 4                    NA                NA              NA
## 5                    NA                NA              NA
## 6                    NA                NA              NA
## 7                    NA                NA              NA
## 8                    NA                NA              NA
## 12                   NA                NA              NA
## 13                   NA                NA              NA
## 14                   NA                NA              NA
##    stddev_yaw_forearm var_yaw_forearm gyros_forearm_x gyros_forearm_y
## 2                  NA              NA            0.02            0.00
## 3                  NA              NA            0.03           -0.02
## 4                  NA              NA            0.02           -0.02
## 5                  NA              NA            0.02            0.00
## 6                  NA              NA            0.02           -0.02
## 7                  NA              NA            0.02            0.00
## 8                  NA              NA            0.02           -0.02
## 12                 NA              NA            0.02            0.02
## 13                 NA              NA            0.00            0.00
## 14                 NA              NA            0.00           -0.02
##    gyros_forearm_z accel_forearm_x accel_forearm_y accel_forearm_z
## 2            -0.02             192             203            -216
## 3             0.00             196             204            -213
## 4             0.00             189             206            -214
## 5            -0.02             189             206            -214
## 6            -0.03             193             203            -215
## 7            -0.02             195             205            -215
## 8             0.00             193             205            -213
## 12           -0.03             191             203            -215
## 13           -0.03             193             205            -215
## 14           -0.03             193             202            -214
##    magnet_forearm_x magnet_forearm_y magnet_forearm_z classe
```

```
## 2               -18              661              473      A
## 3               -18              658              469      A
## 4               -16              658              469      A
## 5               -17              655              473      A
## 6                -9              660              478      A
## 7               -18              659              470      A
## 8                -9              660              474      A
## 12              -11              657              478      A
## 13              -15              655              472      A
## 14              -14              659              478      A
```

Below is the summary of the data **after cleaning** which was used for training the model.

```
summary (myCleanTrain)
```

```
##    num_window      roll_belt         pitch_belt          yaw_belt
##  Min.   :  1.0   Min.   :-28.900   Min.   :-54.7000   Min.   :-180.00
##  1st Qu.:220.8   1st Qu.:  1.097   1st Qu.:  1.7200   1st Qu.: -88.30
##  Median :424.0   Median :113.000   Median :  5.2800   Median : -13.10
##  Mean   :430.1   Mean   : 64.360   Mean   :  0.2414   Mean   : -10.97
##  3rd Qu.:643.0   3rd Qu.:123.000   3rd Qu.: 14.8000   3rd Qu.:  13.43
##  Max.   :864.0   Max.   :162.000   Max.   : 60.2000   Max.   : 179.00
##  total_accel_belt  gyros_belt_x        gyros_belt_y       gyros_belt_z
##  Min.   : 0.00    Min.   :-1.040000   Min.   :-0.51000   Min.   :-1.3500
##  1st Qu.: 3.00    1st Qu.:-0.050000   1st Qu.: 0.00000   1st Qu.:-0.2000
##  Median :17.00    Median : 0.030000   Median : 0.02000   Median :-0.1000
##  Mean   :11.31    Mean   :-0.007288   Mean   : 0.03946   Mean   :-0.1313
##  3rd Qu.:18.00    3rd Qu.: 0.110000   3rd Qu.: 0.11000   3rd Qu.:-0.0200
##  Max.   :28.00    Max.   : 2.220000   Max.   : 0.64000   Max.   : 1.6100
##   accel_belt_x       accel_belt_y     accel_belt_z     magnet_belt_x
##  Min.   :-120.000   Min.   :-69.00   Min.   :-269.00   Min.   :-48.00
##  1st Qu.: -21.000   1st Qu.:  3.00   1st Qu.:-162.00   1st Qu.:  9.00
##  Median : -15.000   Median : 35.00   Median :-152.00   Median : 34.00
##  Mean   :  -5.523   Mean   : 30.12   Mean   : -72.58   Mean   : 55.59
##  3rd Qu.:  -5.000   3rd Qu.: 61.00   3rd Qu.:  27.00   3rd Qu.: 60.00
##  Max.   :  85.000   Max.   :164.00   Max.   : 105.00   Max.   :479.00
##  magnet_belt_y   magnet_belt_z       roll_arm         pitch_arm
##  Min.   :359.0   Min.   :-623.0   Min.   :-180.00   Min.   :-88.800
##  1st Qu.:581.0   1st Qu.:-375.0   1st Qu.: -30.70   1st Qu.:-26.100
##  Median :601.0   Median :-319.5   Median :   0.00   Median :  0.000
##  Mean   :593.7   Mean   :-345.3   Mean   :  18.22   Mean   : -4.643
##  3rd Qu.:610.0   3rd Qu.:-306.0   3rd Qu.:  77.30   3rd Qu.: 11.325
##  Max.   :673.0   Max.   : 293.0   Max.   : 180.00   Max.   : 88.500
##     yaw_arm         total_accel_arm  gyros_arm_x        gyros_arm_y
##  Min.   :-180.000   Min.   : 1.00   Min.   :-6.37000   Min.   :-3.4000
##  1st Qu.: -42.825   1st Qu.:17.00   1st Qu.:-1.32250   1st Qu.:-0.8000
##  Median :   0.000   Median :27.00   Median : 0.08000   Median :-0.2600
##  Mean   :  -1.099   Mean   :25.57   Mean   : 0.04716   Mean   :-0.2587
##  3rd Qu.:  45.300   3rd Qu.:33.00   3rd Qu.: 1.59000   3rd Qu.: 0.1400
##  Max.   : 180.000   Max.   :66.00   Max.   : 4.87000   Max.   : 2.8400
##   gyros_arm_z      accel_arm_x       accel_arm_y       accel_arm_z
##  Min.   :-2.330   Min.   :-383.00   Min.   :-318.00   Min.   :-636.00
##  1st Qu.:-0.070   1st Qu.:-242.00   1st Qu.: -54.00   1st Qu.:-144.00
```

```
##  Median : 0.230   Median : -41.00   Median :  14.00   Median : -46.00
##  Mean   : 0.271   Mean   : -58.62   Mean   :  32.41   Mean   : -71.62
##  3rd Qu.: 0.720   3rd Qu.:  84.00   3rd Qu.: 138.00   3rd Qu.:  23.00
##  Max.   : 3.020   Max.   : 437.00   Max.   : 308.00   Max.   : 292.00
##   magnet_arm_x     magnet_arm_y     magnet_arm_z    roll_dumbbell
##  Min.   :-584.0   Min.   :-384.0   Min.   :-597.0   Min.   :-153.71
##  1st Qu.:-297.0   1st Qu.: -11.0   1st Qu.: 123.0   1st Qu.: -18.48
##  Median : 293.0   Median : 200.0   Median : 443.0   Median :  48.41
##  Mean   : 194.1   Mean   : 155.8   Mean   : 304.2   Mean   :  23.73
##  3rd Qu.: 640.0   3rd Qu.: 323.0   3rd Qu.: 545.0   3rd Qu.:  67.46
##  Max.   : 782.0   Max.   : 583.0   Max.   : 694.0   Max.   : 153.55
##  pitch_dumbbell     yaw_dumbbell      total_accel_dumbbell
##  Min.   :-148.50   Min.   :-150.871   Min.   : 0.00
##  1st Qu.: -40.81   1st Qu.: -77.745   1st Qu.: 5.00
##  Median : -20.90   Median :  -3.569   Median :11.00
##  Mean   : -10.81   Mean   :   1.633   Mean   :13.77
##  3rd Qu.:  17.38   3rd Qu.:  79.808   3rd Qu.:20.00
##  Max.   : 149.40   Max.   : 154.952   Max.   :58.00
##  gyros_dumbbell_x    gyros_dumbbell_y   gyros_dumbbell_z
##  Min.   :-204.0000   Min.   :-2.10000   Min.   : -1.950
##  1st Qu.:  -0.0300   1st Qu.:-0.14000   1st Qu.: -0.310
##  Median :   0.1400   Median : 0.05000   Median : -0.130
##  Mean   :   0.1574   Mean   : 0.04765   Mean   : -0.123
##  3rd Qu.:   0.3500   3rd Qu.: 0.21000   3rd Qu.:  0.030
##  Max.   :   2.2000   Max.   :52.00000   Max.   :317.000
##  accel_dumbbell_x  accel_dumbbell_y  accel_dumbbell_z  magnet_dumbbell_x
##  Min.   :-419.00   Min.   :-179.00   Min.   :-334.00   Min.   :-643.0
##  1st Qu.: -50.00   1st Qu.:  -9.00   1st Qu.:-142.00   1st Qu.:-535.0
##  Median :  -8.00   Median :  43.00   Median :  -1.00   Median :-479.0
##  Mean   : -28.42   Mean   :  52.84   Mean   : -38.71   Mean   :-325.1
##  3rd Qu.:  11.00   3rd Qu.: 111.00   3rd Qu.:  39.00   3rd Qu.:-294.0
##  Max.   : 235.00   Max.   : 315.00   Max.   : 318.00   Max.   : 584.0
##  magnet_dumbbell_y magnet_dumbbell_z  roll_forearm       pitch_forearm
##  Min.   :-744      Min.   :-250.00   Min.   :-180.0000   Min.   :-72.500
##  1st Qu.: 231      1st Qu.: -46.00   1st Qu.:  -0.6625   1st Qu.:  0.000
##  Median : 310      Median :  13.00   Median :  21.1000   Median :  9.595
##  Mean   : 219      Mean   :  45.84   Mean   :  34.0147   Mean   : 10.955
##  3rd Qu.: 390      3rd Qu.:  94.25   3rd Qu.: 140.0000   3rd Qu.: 28.600
##  Max.   : 632      Max.   : 452.00   Max.   : 180.0000   Max.   : 89.800
##   yaw_forearm      total_accel_forearm gyros_forearm_x
##  Min.   :-180.00   Min.   :  0.00      Min.   :-22.0000
##  1st Qu.: -68.80   1st Qu.: 29.00      1st Qu.: -0.2200
##  Median :   0.00   Median : 36.00      Median :  0.0500
##  Mean   :  19.03   Mean   : 34.77      Mean   :  0.1602
##  3rd Qu.: 110.00   3rd Qu.: 41.00      3rd Qu.:  0.5800
##  Max.   : 180.00   Max.   :108.00      Max.   :  3.9700
##  gyros_forearm_y     gyros_forearm_z    accel_forearm_x   accel_forearm_y
##  Min.   : -7.02000   Min.   : -6.9900   Min.   :-498.00   Min.   :-632.0
##  1st Qu.: -1.48000   1st Qu.: -0.1800   1st Qu.:-179.00   1st Qu.:  54.0
##  Median :  0.03000   Median :  0.0800   Median : -57.00   Median : 201.0
##  Mean   :  0.08144   Mean   :  0.1568   Mean   : -61.97   Mean   : 163.7
##  3rd Qu.:  1.64000   3rd Qu.:  0.4900   3rd Qu.:  76.00   3rd Qu.: 312.0
##  Max.   :311.00000   Max.   :231.0000   Max.   : 389.00   Max.   : 923.0
##  accel_forearm_z  magnet_forearm_x  magnet_forearm_y  magnet_forearm_z
```

```
##  Min.   :-410.0   Min.   :-1280.0   Min.   :-896.00   Min.   :-966.0
##  1st Qu.:-183.0   1st Qu.: -617.0   1st Qu.:  -2.25   1st Qu.: 193.0
##  Median : -42.0   Median : -383.0   Median : 587.00   Median : 511.0
##  Mean   : -56.5   Mean   : -314.6   Mean   : 376.17   Mean   : 395.3
##  3rd Qu.:  25.0   3rd Qu.:  -77.0   3rd Qu.: 736.00   3rd Qu.: 652.0
##  Max.   : 287.0   Max.   :  672.0   Max.   :1480.00   Max.   :1090.0
##  classe
##  A:3830
##  B:2601
##  C:2345
##  D:2212
##  E:2476
##
```

```
head (myCleanTrain, 10)
```

```
##    num_window roll_belt pitch_belt yaw_belt total_accel_belt gyros_belt_x
## 2          11      1.41       8.07    -94.4                3         0.02
## 3          11      1.42       8.07    -94.4                3         0.00
## 4          12      1.48       8.05    -94.4                3         0.02
## 5          12      1.48       8.07    -94.4                3         0.02
## 6          12      1.45       8.06    -94.4                3         0.02
## 7          12      1.42       8.09    -94.4                3         0.02
## 8          12      1.42       8.13    -94.4                3         0.02
## 12         12      1.43       8.18    -94.4                3         0.02
## 13         12      1.42       8.20    -94.4                3         0.02
## 14         12      1.42       8.21    -94.4                3         0.02
##    gyros_belt_y gyros_belt_z accel_belt_x accel_belt_y accel_belt_z
## 2          0.00        -0.02          -22            4           22
## 3          0.00        -0.02          -20            5           23
## 4          0.00        -0.03          -22            3           21
## 5          0.02        -0.02          -21            2           24
## 6          0.00        -0.02          -21            4           21
## 7          0.00        -0.02          -22            3           21
## 8          0.00        -0.02          -22            4           21
## 12         0.00        -0.02          -22            2           23
## 13         0.00         0.00          -22            4           21
## 14         0.00        -0.02          -22            4           21
##    magnet_belt_x magnet_belt_y magnet_belt_z roll_arm pitch_arm yaw_arm
## 2             -7           608          -311     -128      22.5    -161
## 3             -2           600          -305     -128      22.5    -161
## 4             -6           604          -310     -128      22.1    -161
## 5             -6           600          -302     -128      22.1    -161
## 6              0           603          -312     -128      22.0    -161
## 7             -4           599          -311     -128      21.9    -161
## 8             -2           603          -313     -128      21.8    -161
## 12            -2           602          -319     -128      21.5    -161
## 13            -3           606          -309     -128      21.4    -161
## 14            -8           598          -310     -128      21.4    -161
##    total_accel_arm gyros_arm_x gyros_arm_y gyros_arm_z accel_arm_x
## 2               34        0.02       -0.02       -0.02        -290
## 3               34        0.02       -0.02       -0.02        -289
## 4               34        0.02       -0.03        0.02        -289
## 5               34        0.00       -0.03        0.00        -289
```

```
## 6               34        0.02       -0.03        0.00        -289
## 7               34        0.00       -0.03        0.00        -289
## 8               34        0.02       -0.02        0.00        -289
## 12              34        0.02       -0.03        0.00        -288
## 13              34        0.02       -0.02       -0.02        -287
## 14              34        0.02        0.00       -0.03        -288
##    accel_arm_y accel_arm_z magnet_arm_x magnet_arm_y magnet_arm_z
## 2          110        -125         -369          337          513
## 3          110        -126         -368          344          513
## 4          111        -123         -372          344          512
## 5          111        -123         -374          337          506
## 6          111        -122         -369          342          513
## 7          111        -125         -373          336          509
## 8          111        -124         -372          338          510
## 12         111        -123         -363          343          520
## 13         111        -124         -372          338          509
## 14         111        -124         -371          331          523
##    roll_dumbbell pitch_dumbbell yaw_dumbbell total_accel_dumbbell
## 2       13.13074      -70.63751    -84.71065                   37
## 3       12.85075      -70.27812    -85.14078                   37
## 4       13.43120      -70.39379    -84.87363                   37
## 5       13.37872      -70.42856    -84.85306                   37
## 6       13.38246      -70.81759    -84.46500                   37
## 7       13.12695      -70.24757    -85.09961                   37
## 8       12.75083      -70.34768    -85.09708                   37
## 12      13.10321      -70.45975    -84.89472                   37
## 13      13.38246      -70.81759    -84.46500                   37
## 14      13.41048      -70.99594    -84.28005                   37
##    gyros_dumbbell_x gyros_dumbbell_y gyros_dumbbell_z accel_dumbbell_x
## 2              0.00            -0.02             0.00             -233
## 3              0.00            -0.02             0.00             -232
## 4              0.00            -0.02            -0.02             -232
## 5              0.00            -0.02             0.00             -233
## 6              0.00            -0.02             0.00             -234
## 7              0.00            -0.02             0.00             -232
## 8              0.00            -0.02             0.00             -234
## 12             0.00            -0.02             0.00             -233
## 13             0.00            -0.02            -0.02             -234
## 14             0.02            -0.02            -0.02             -234
##    accel_dumbbell_y accel_dumbbell_z magnet_dumbbell_x magnet_dumbbell_y
## 2                47             -269              -555               296
## 3                46             -270              -561               298
## 4                48             -269              -552               303
## 5                48             -270              -554               292
## 6                48             -269              -558               294
## 7                47             -270              -551               295
## 8                46             -272              -555               300
## 12               47             -270              -554               291
## 13               48             -269              -552               302
## 14               48             -268              -554               295
##    magnet_dumbbell_z roll_forearm pitch_forearm yaw_forearm
## 2                -64         28.3        -63.9       -153
## 3                -63         28.3        -63.9       -152
## 4                -60         28.1        -63.9       -152
```

```
## 5                -68         28.0         -63.9        -152
## 6                -66         27.9         -63.9        -152
## 7                -70         27.9         -63.9        -152
## 8                -74         27.8         -63.8        -152
## 12               -65         27.5         -63.8        -152
## 13               -69         27.2         -63.9        -151
## 14               -68         27.2         -63.9        -151
##    total_accel_forearm gyros_forearm_x gyros_forearm_y gyros_forearm_z
## 2                   36            0.02            0.00           -0.02
## 3                   36            0.03           -0.02            0.00
## 4                   36            0.02           -0.02            0.00
## 5                   36            0.02            0.00           -0.02
## 6                   36            0.02           -0.02           -0.03
## 7                   36            0.02            0.00           -0.02
## 8                   36            0.02           -0.02            0.00
## 12                  36            0.02            0.02           -0.03
## 13                  36            0.00            0.00           -0.03
## 14                  36            0.00           -0.02           -0.03
##    accel_forearm_x accel_forearm_y accel_forearm_z magnet_forearm_x
## 2              192             203            -216              -18
## 3              196             204            -213              -18
## 4              189             206            -214              -16
## 5              189             206            -214              -17
## 6              193             203            -215               -9
## 7              195             205            -215              -18
## 8              193             205            -213               -9
## 12             191             203            -215              -11
## 13             193             205            -215              -15
## 14             193             202            -214              -14
##    magnet_forearm_y magnet_forearm_z classe
## 2               661              473      A
## 3               658              469      A
## 4               658              469      A
## 5               655              473      A
## 6               660              478      A
## 7               659              470      A
## 8               660              474      A
## 12              657              478      A
## 13              655              472      A
## 14              659              478      A
```