

# Practical Machine Learning Course Project

## Practical Machine Learning Course Peer Graded Assignment

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### Synopsis

This report analyzes data collected from belt, forearm, arm, and dumbbell accelerometers of 6 participants, in order to predict the manner in which they did their exercise. Participants were asked to perform one set of 10 repetitions of the Unilateral Dumbbell Biceps Curl in five different fashions: 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). Class A corresponds to the specified execution of the exercise, while the other 4 classes correspond to common mistakes.

Using devices such as Jawbone Up, Nike FuelBand, and Fitbit it is now possible to collect a large amount of data about personal activity relatively inexpensively. These type of devices are part of the quantified self movement – a group of enthusiasts who take measurements about themselves regularly to improve their health, to find patterns in their behavior, or just because they are tech geeks. One thing that people regularly do is quantify how much of a particular activity they do, but they rarely quantify how well they do it. In this project, your goal will be to use data from accelerometers on the belt, forearm, arm, and dumbbell of 6 participants, and predict the manner in which participants did the exercise. The *classe* variable in the training set takes on 1 of the 5 Classes (i.e. A, B, C, D, E).

More information is available from the website here: <http://groupware.les.inf.puc-rio.br/har> (see the section on the Weight Lifting Exercise Dataset).

### Data

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

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

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

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## Data loading and pre-processing

```
# Data setup
data.training <- read.csv("pml-training.csv", header = TRUE, sep = ",")
data.testing <- read.csv("pml-testing.csv", header = TRUE, sep = ",")
```

**Training set** basic properties inspection is shown at Appendix #1. We see 19622 samples from 6 individuals (adelmo, carlitos, charles, eurico, jeremy, pedro), where the *classe* factor variable can take any of the values *A, B, C, D, E*.

**Testing set** is shown at Appendix #2. We see 20 samples from the same 6 individuals (adelmo, carlitos, charles, eurico, jeremy, pedro), where the *classe* variable has been replaced by a *problem\_id* integer variable with incremental values in the range 1 – 20.

### Remove some variables

Then, it is observed that the first *X* variable is an incremental row counter, in both sets. And the remained variables are either numeric/integer or categorical (factor) variables. The categorical variables most probably indicate several sensor devices settings, so we remove them from both data sets prior to data analysis. We also remove the *X* row counters. The categorical variables to be removed from both data sets, are:

```
# Identify all categorical (factor) variable names
factor.vars <- split(names(data.training), sapply(data.training, function(x)
  paste(class(x), collapse=" ")))$factor
print(factor.vars <- factor.vars[-which(factor.vars == 'classe')])
```

```
## [1] "user_name"          "cvtd_timestamp"
## [3] "new_window"         "kurtosis_roll_belt"
## [5] "kurtosis_picth_belt" "kurtosis_yaw_belt"
## [7] "skewness_roll_belt" "skewness_roll_belt.1"
## [9] "skewness_yaw_belt"  "max_yaw_belt"
## [11] "min_yaw_belt"       "amplitude_yaw_belt"
## [13] "kurtosis_roll_arm"  "kurtosis_picth_arm"
## [15] "kurtosis_yaw_arm"   "skewness_roll_arm"
## [17] "skewness_pitch_arm" "skewness_yaw_arm"
## [19] "kurtosis_roll_dumbbell" "kurtosis_picth_dumbbell"
## [21] "kurtosis_yaw_dumbbell" "skewness_roll_dumbbell"
## [23] "skewness_pitch_dumbbell" "skewness_yaw_dumbbell"
## [25] "max_yaw_dumbbell"   "min_yaw_dumbbell"
## [27] "amplitude_yaw_dumbbell" "kurtosis_roll_forearm"
## [29] "kurtosis_picth_forearm" "kurtosis_yaw_forearm"
## [31] "skewness_roll_forearm" "skewness_pitch_forearm"
## [33] "skewness_yaw_forearm" "max_yaw_forearm"
## [35] "min_yaw_forearm"    "amplitude_yaw_forearm"
```

From those, we keep only the *classe* training variable while we also remove the *problem\_id* testing variable.

```
# Remove some variables
training <- data.training[, -which(names(data.training) %in%
  c('X', factor.vars))]
testing <- data.testing[, -which(names(data.testing) %in%
  c('X', factor.vars, 'problem_id'))]
```

## Remove N/A variables

```
# Remove N/A and blank variables
print(na.vars <- names(which(sapply(training, function(x) length(which(is.na(x)))!=0))))
```

```
## [1] "max_roll_belt"          "max_picth_belt"
## [3] "min_roll_belt"          "min_pitch_belt"
## [5] "amplitude_roll_belt"    "amplitude_pitch_belt"
## [7] "var_total_accel_belt"   "avg_roll_belt"
## [9] "stddev_roll_belt"       "var_roll_belt"
## [11] "avg_pitch_belt"         "stddev_pitch_belt"
## [13] "var_pitch_belt"         "avg_yaw_belt"
## [15] "stddev_yaw_belt"        "var_yaw_belt"
## [17] "var_accel_arm"          "avg_roll_arm"
## [19] "stddev_roll_arm"        "var_roll_arm"
## [21] "avg_pitch_arm"          "stddev_pitch_arm"
## [23] "var_pitch_arm"          "avg_yaw_arm"
## [25] "stddev_yaw_arm"         "var_yaw_arm"
## [27] "max_roll_arm"           "max_picth_arm"
## [29] "max_yaw_arm"            "min_roll_arm"
## [31] "min_pitch_arm"          "min_yaw_arm"
## [33] "amplitude_roll_arm"     "amplitude_pitch_arm"
## [35] "amplitude_yaw_arm"       "max_roll_dumbbell"
## [37] "max_picth_dumbbell"     "min_roll_dumbbell"
## [39] "min_pitch_dumbbell"     "amplitude_roll_dumbbell"
## [41] "amplitude_pitch_dumbbell" "var_accel_dumbbell"
## [43] "avg_roll_dumbbell"       "stddev_roll_dumbbell"
## [45] "var_roll_dumbbell"       "avg_pitch_dumbbell"
## [47] "stddev_pitch_dumbbell"   "var_pitch_dumbbell"
## [49] "avg_yaw_dumbbell"        "stddev_yaw_dumbbell"
## [51] "var_yaw_dumbbell"        "max_roll_forearm"
## [53] "max_picth_forearm"       "min_roll_forearm"
## [55] "min_pitch_forearm"       "amplitude_roll_forearm"
## [57] "amplitude_pitch_forearm" "var_accel_forearm"
## [59] "avg_roll_forearm"        "stddev_roll_forearm"
## [61] "var_roll_forearm"        "avg_pitch_forearm"
## [63] "stddev_pitch_forearm"    "var_pitch_forearm"
## [65] "avg_yaw_forearm"         "stddev_yaw_forearm"
## [67] "var_yaw_forearm"
```

From the remained variables, we identify 67 variables with *N/A* values, and remove them as well:

```
# Remove N/A and blank variables
training <- training[, -which(names(training) %in% na.vars)]
testing <- testing[, -which(names(testing) %in% na.vars)]
```

## Final variables to remove

From the remained variables, the *raw\_timestamp\_part\_1*, *raw\_timestamp\_part\_2*, and *num\_window* variables are also selected to be removed as they carry not measured values:

```
# Remove some more variables
print(somemore.vars <- c('raw_timestamp_part_1', 'raw_timestamp_part_2', 'num_window'))
```

```
## [1] "raw_timestamp_part_1" "raw_timestamp_part_2" "num_window"
```

```
training <- training[, -which(names(training) %in% somemore.vars)]
testing <- testing[, -which(names(testing) %in% somemore.vars)]
```

Then, the remaining variables to work with, are:

- 52 predictor variables, and
- the *classe* classifier (predicted variable):

```
# Variables to work with
names(training)
```

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

```
dim(training)
```

```
## [1] 19622    53
```

```
dim(testing)
```

```
## [1] 20 52
```

# Data Processing

```
# Set some working settings
part_perc <- 0.7          # partition percentage
modelFitNbr <- 10         # Model(s) fit number
rf_ntrees <- 100          # Number of trees to grow (random forest model)
rf_ntrees.tune <- 500     # Number of trees to grow (when tuning)
seed0 <- 1235             # Random seeding value
```

## Data partitioning

Before creating our model, we split the training data set into a working training set with the 70% of the samples, and a validation set with the remaining 30% of the training samples.

```
# Split training data set, create a validation set
featuresPartition <- createDataPartition(y = training$classe, p = part_perc, list = FALSE)
training.train <- training[featuresPartition,]
training.validate <- training[-featuresPartition,]
dim(training.train)
```

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

```
dim(training.validate)
```

```
## [1] 5885    53
```

This creates a new training set with 13737 entries and a new validation set with 5885 entries, out of our original training set. The plan is to use the working training set for training our model and the validation set to test (and fine tune) it, before applying it to the original testing set.

## Model selection

In order to select the optimal prediction model, we will create several different models, train them, and measure their predictions accuracy (using the working training and validation data sets as created above). Then, we will select the optimal accuracy model to proceed with. The candidate models to test are:

- Decision tree model, or CART (Classification And Regression Tree), and
- Random Forest model.

```
# Model selection process
fitControl <- trainControl(method = "cv", number = modelFitNbr)
# train the models
set.seed(seed0)
model.CART <- train(classe ~ ., data = training.train, trControl = fitControl, method = "rpart")
set.seed(seed0)
model.RF <- train(classe ~ ., data = training.train, trControl = fitControl, method = "rf",
                  ntree = rf_ntrees)
```

(\*) Note: Training the models is quite computational demanding.

After training the models, we use them in order to predict the (known to us) validation set classifier variable and measure their prediction accuracy:

```
# Models prediction accuracy
pred.CART <- predict(model.CART, newdata = training.validate)
pred.RF <- predict(model.RF, newdata = training.validate)
# measure predictions accuracy
cm.CART <- confusionMatrix(pred.CART, training.validate$classe)
cm.RF <- confusionMatrix(pred.RF, training.validate$classe)
# compare models accuracy
print(accuracy.comp <- data.frame(Model = c('CART', 'RF'),
                                   Accuracy = rbind(round(cm.CART$overall[1],3),
                                                    round(cm.RF$overall[1],3))))
```

```
##   Model Accuracy
## 1  CART      0.486
## 2   RF      0.991
```

Based on the above models accuracy comparison table, **we choose to proceed with the Random Forest model.**

## Validation Out-of-Sample Error

```
# Validation predictions accuracy table
table(pred.RF, training.validate$classe)
```

```
##
## pred.RF   A    B    C    D    E
##      A 1674   13    0    0    0
##      B   0 1121   13    0    0
##      C   0   5 1010   15    1
##      D   0   0   3  947    1
##      E   0   0   0   2 1080
```

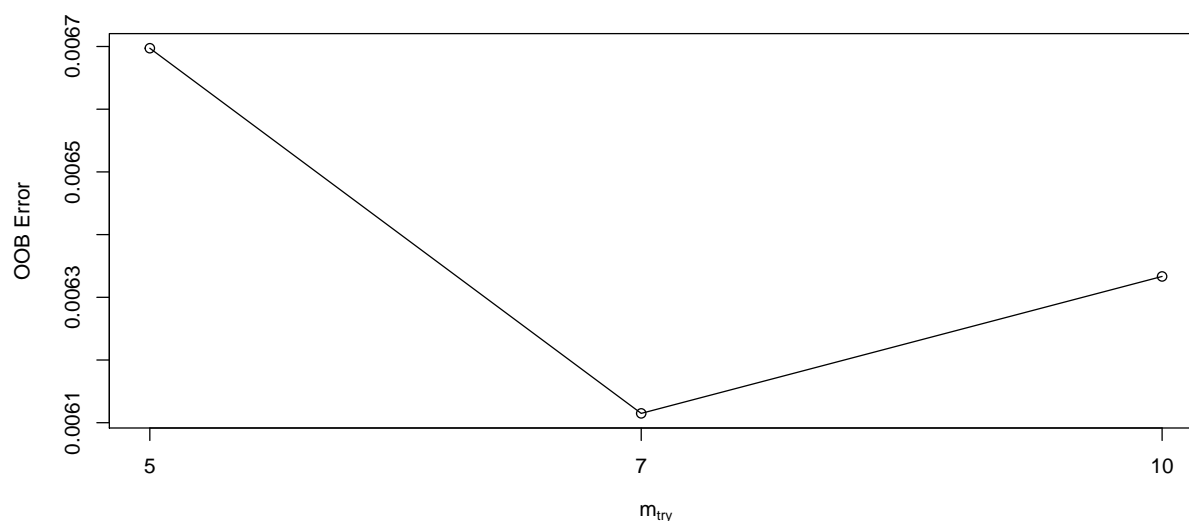
```
# Validation Out-of-Sample Error
correct.predictions <- sum(pred.RF == training.validate$classe)
wrong.predictions <- sum(pred.RF != training.validate$classe)
OoSError <- 1 - correct.predictions / nrow(training.validate)
```

Our model correctly predicted 5832 while it missed 53 values of the validation data set. This corresponds to a 0.0090059 (or 0.9%) out-of-sample error.

## Model tuning

```
# Random Forest model tuning
set.seed(seed0)
bestmtry <- tuneRF(training.train[-which(names(training.train) == 'classe')],
                  training.train$classe, ntreeTry = rf_ntrees,
                  stepFactor = 1.5, improve = 0.01,
                  trace = TRUE, plot = TRUE, dobest = FALSE)
```

```
## mtry = 7   OOB error = 0.61%
## Searching left ...
## mtry = 5   OOB error = 0.67%
## -0.0952381 0.01
## Searching right ...
## mtry = 10  OOB error = 0.63%
## -0.03571429 0.01
```



```
best.mtry <- bestmtry[as.numeric(which.min(bestmtry[, "OOBError"])), "mtry"]
best.OOBError <- bestmtry[as.numeric(which.min(bestmtry[, "OOBError"])), "OOBError"]
```

As shown at the above *tuneRF()* diagram, the *mtry* value 7 gives the lowest OOB Error (0.0061149). So, our random forest model will be tuned based on this:

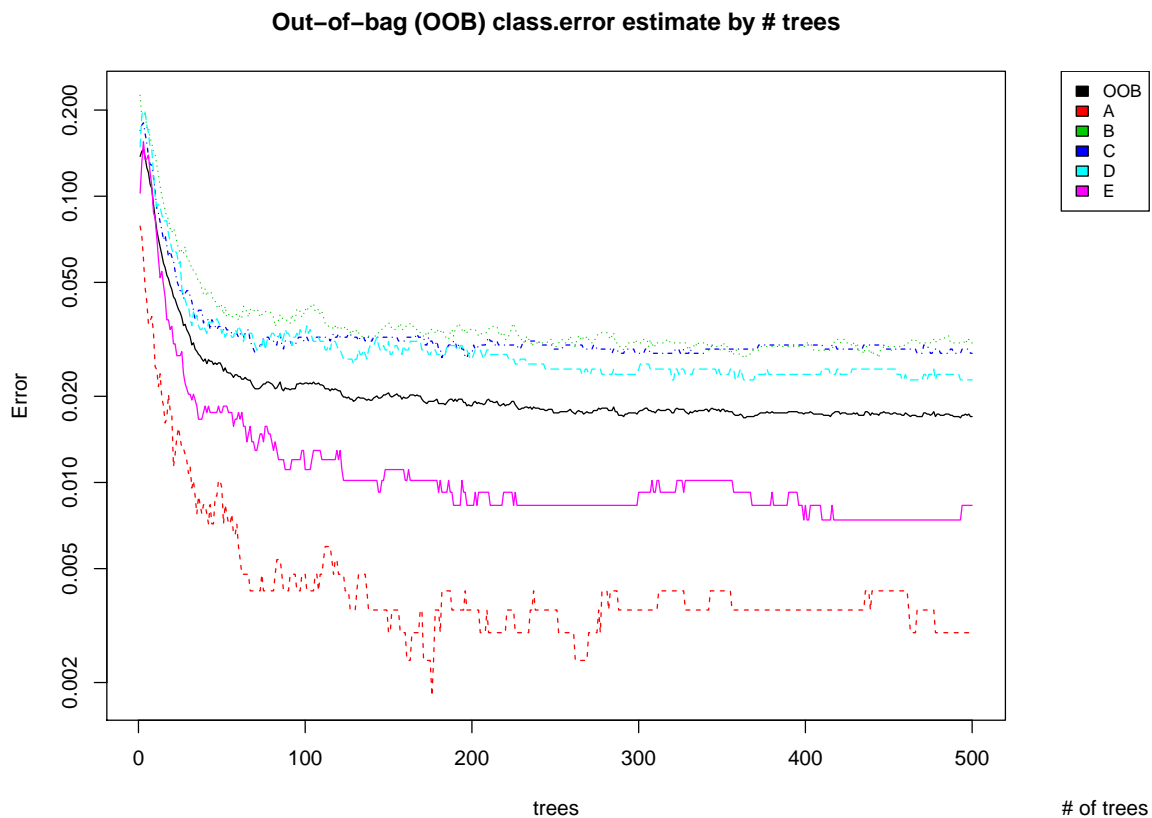
```
set.seed(seed0)
# Model tuning
model.tuned <- randomForest(classe ~ ., data = training.validate, mtry = best.mtry,
                           ntree = rf_ntrees.tune, keep.forest = TRUE, proximity = TRUE,
                           importance = TRUE, test = training.validate)

model.tuned
```

```
##
```

```
## Call:
## randomForest(formula = classe ~ ., data = training.validate, mtry = best.mtry, ntree = rf_ntree)
##           Type of random forest: classification
##           Number of trees: 500
## No. of variables tried at each split: 7
##
##           OOB estimate of  error rate: 1.7%
## Confusion matrix:
##      A      B      C      D      E class.error
## A 1669      4      1      0      0 0.002986858
## B   25 1104      9      1      0 0.030728709
## C    0   28 997      1      0 0.028265107
## D    0    0 22 942      0 0.022821577
## E    0    0  5   4 1073 0.008317930
```

```
# Plot the Out-of-bag error estimates
layout(matrix(c(1, 2), nrow = 1), width = c(4, 1))
par(mar = c(5, 4, 4, 0))
plot(model.tuned, log = "y", main = "Out-of-bag (OOB) class.error estimate by # trees")
par(mar = c(5, 0, 4, 2))
plot(c(0, 1), type = "n", axes = F, xlab = "# of trees", ylab = "Class. error")
legend("top", colnames(model.tuned$err.rate), col = 1:6, cex = 0.8, fill = 1:6)
```

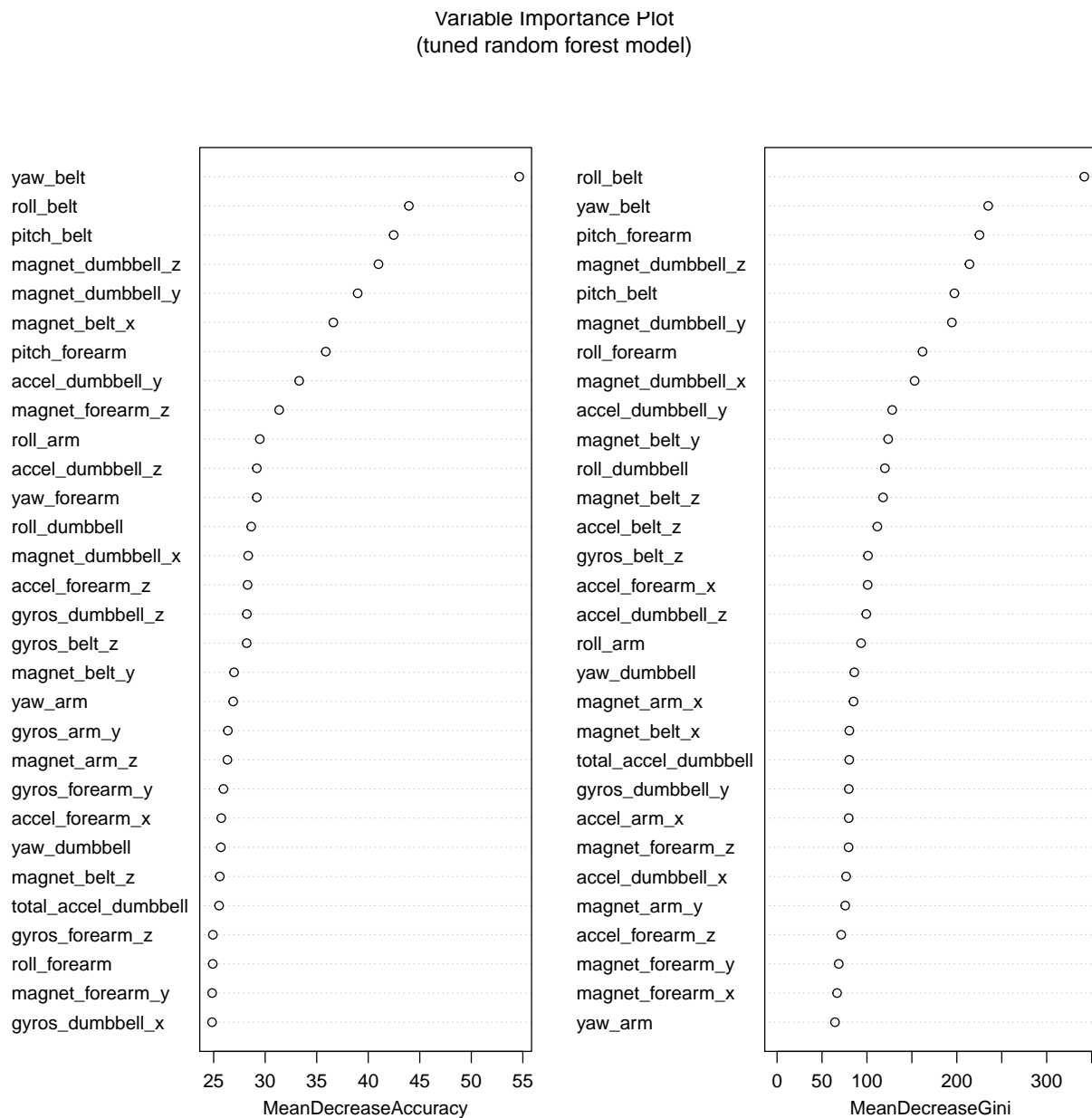




## Variable importance

We can also see the model variables' importance at the following Variable Importance Plot:

```
# Variable Importance Plot
varImpPlot(model.tuned, main="Variable Importance Plot\n(tuned random forest model)")
```



## Testing set prediction

Finally, we apply the model built on the original testing data set, in order to predict the 20 samples' *classe* variable:

```
# Testing set prediction
predictions <- predict(model.tuned, newdata = testing)
data.frame('Classe(Predicted)' = predictions)
```

```
##      Classe.Predicted.
## 1                    B
## 2                    A
## 3                    B
## 4                    A
## 5                    A
## 6                    E
## 7                    D
## 8                    B
## 9                    A
## 10                   A
## 11                   B
## 12                   C
## 13                   B
## 14                   A
## 15                   E
## 16                   E
## 17                   A
## 18                   B
## 19                   B
## 20                   B
```

---

# Appendix #1

## Training set inspection

```
# Instant data touching
levels(data.training$user_name)
```

```
## [1] "adelmo" "carlitos" "charles" "eurico" "jeremy" "pedro"
```

```
levels(data.training$classe)
```

```
## [1] "A" "B" "C" "D" "E"
```

```
str(data.training, list.len = 999)
```

```
## '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 484...
## $ 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 ...
## $ 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 NA NA ...
## $ max_pitch_belt : int NA NA 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 NA NA ...
## $ min_pitch_belt : int NA NA 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 ...
## $ amplitude_roll_belt : num NA NA NA NA NA NA NA NA NA NA ...
## $ amplitude_pitch_belt : int NA NA NA NA NA NA NA NA NA NA ...
## $ amplitude_yaw_belt : Factor w/ 4 levels "", "#DIV/0!", "0.00",...: 1 1 1 1 1 1 1 1 1 1 ...
## $ var_total_accel_belt : num NA NA NA NA NA NA NA NA NA NA ...
## $ avg_roll_belt : num NA NA NA NA NA NA NA NA NA NA ...
## $ stddev_roll_belt : num NA NA NA NA NA NA NA NA NA NA ...
## $ var_roll_belt : num NA NA NA NA NA NA NA NA NA NA ...
## $ avg_pitch_belt : num NA NA NA NA NA NA NA NA NA NA ...
## $ stddev_pitch_belt : num NA NA NA NA NA NA NA NA NA NA ...
## $ var_pitch_belt : num NA NA NA NA NA NA NA NA NA NA ...
## $ avg_yaw_belt : num NA NA NA NA NA NA NA NA NA NA ...
```

```

## $ stddev_yaw_belt      : num  NA NA NA NA NA NA NA NA NA NA NA ...
## $ var_yaw_belt        : num  NA NA NA NA NA NA NA NA NA NA NA ...
## $ gyros_belt_x        : num  0 0.02 0 0.02 0.02 0.02 0.02 0.02 0.02 0.03 ...
## $ gyros_belt_y        : num  0 0 0 0 0.02 0 0 0 0 0 ...
## $ gyros_belt_z        : num  -0.02 -0.02 -0.02 -0.03 -0.02 -0.02 -0.02 -0.02 -0.02 0 ...
## $ accel_belt_x        : int   -21 -22 -20 -22 -21 -21 -22 -22 -20 -21 ...
## $ accel_belt_y        : int    4 4 5 3 2 4 3 4 2 4 ...
## $ accel_belt_z        : int   22 22 23 21 24 21 21 21 24 22 ...
## $ magnet_belt_x       : int    -3 -7 -2 -6 -6 0 -4 -2 1 -3 ...
## $ magnet_belt_y       : int   599 608 600 604 600 603 599 603 602 609 ...
## $ magnet_belt_z       : int  -313 -311 -305 -310 -302 -312 -311 -313 -312 -308 ...
## $ roll_arm            : num  -128 -128 -128 -128 -128 -128 -128 -128 -128 -128 ...
## $ pitch_arm           : num   22.5 22.5 22.5 22.1 22.1 22 21.9 21.8 21.7 21.6 ...
## $ yaw_arm            : num  -161 -161 -161 -161 -161 -161 -161 -161 -161 -161 ...
## $ total_accel_arm     : int   34 34 34 34 34 34 34 34 34 34 ...
## $ var_accel_arm       : num  NA NA NA NA NA NA NA NA NA NA NA ...
## $ avg_roll_arm        : num  NA NA NA NA NA NA NA NA NA NA NA ...
## $ stddev_roll_arm     : num  NA NA NA NA NA NA NA NA NA NA NA ...
## $ var_roll_arm        : num  NA NA NA NA NA NA NA NA NA NA NA ...
## $ avg_pitch_arm       : num  NA NA NA NA NA NA NA NA NA NA NA ...
## $ stddev_pitch_arm    : num  NA NA NA NA NA NA NA NA NA NA NA ...
## $ var_pitch_arm       : num  NA NA NA NA NA NA NA NA NA NA NA ...
## $ avg_yaw_arm         : num  NA NA NA NA NA NA NA NA NA NA NA ...
## $ stddev_yaw_arm      : num  NA NA NA NA NA NA NA NA NA NA NA ...
## $ var_yaw_arm         : num  NA NA NA NA NA NA NA NA NA NA NA ...
## $ gyros_arm_x         : num  0 0.02 0.02 0.02 0 0.02 0 0.02 0.02 0.02 ...
## $ gyros_arm_y         : num  0 -0.02 -0.02 -0.03 -0.03 -0.03 -0.03 -0.02 -0.03 -0.03 ...
## $ gyros_arm_z         : num  -0.02 -0.02 -0.02 0.02 0 0 0 0 -0.02 -0.02 ...
## $ accel_arm_x         : int  -288 -290 -289 -289 -289 -289 -289 -289 -288 -288 ...
## $ accel_arm_y         : int   109 110 110 111 111 111 111 111 109 110 ...
## $ accel_arm_z         : int  -123 -125 -126 -123 -123 -122 -125 -124 -122 -124 ...
## $ magnet_arm_x        : int  -368 -369 -368 -372 -374 -369 -373 -372 -369 -376 ...
## $ magnet_arm_y        : int   337 337 344 344 337 342 336 338 341 334 ...
## $ magnet_arm_z        : int   516 513 513 512 506 513 509 510 518 516 ...
## $ kurtosis_roll_arm   : 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 NA NA NA ...
## $ max_pitch_arm       : num  NA NA NA NA NA NA NA NA NA NA NA ...
## $ max_yaw_arm         : int   NA NA NA NA NA NA NA NA NA NA NA ...
## $ min_roll_arm        : num  NA NA NA NA NA NA NA NA NA NA NA ...
## $ min_pitch_arm       : num  NA NA NA NA NA NA NA NA NA NA NA ...
## $ min_yaw_arm         : int   NA NA NA NA NA NA NA NA NA NA NA ...
## $ amplitude_roll_arm  : num  NA NA NA NA NA NA NA NA NA NA NA ...
## $ amplitude_pitch_arm : num  NA NA NA NA NA NA NA NA NA NA NA ...
## $ amplitude_yaw_arm   : int   NA NA NA NA NA NA NA NA NA NA NA ...
## $ roll_dumbbell       : num  13.1 13.1 12.9 13.4 13.4 ...
## $ pitch_dumbbell      : num  -70.5 -70.6 -70.3 -70.4 -70.4 ...
## $ yaw_dumbbell        : num  -84.9 -84.7 -85.1 -84.9 -84.9 ...
## $ kurtosis_roll_dumbbell : 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 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 1 ...
## $ max_roll_dumbbell : num NA NA NA NA NA NA NA NA NA NA NA ...
## $ max_pitch_dumbbell : num NA NA 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 1 ...
## $ min_roll_dumbbell : num NA NA NA NA NA NA NA NA NA NA NA ...
## $ min_pitch_dumbbell : num NA NA 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 1 ...
## $ amplitude_roll_dumbbell : num NA NA NA NA NA NA NA NA NA NA NA ...
## $ amplitude_pitch_dumbbell : num NA NA NA NA NA NA NA NA NA NA NA ...
## $ amplitude_yaw_dumbbell : Factor w/ 3 levels "", "#DIV/0!", "0.00": 1 1 1 1 1 1 1 1 1 1 ...
## $ total_accel_dumbbell : int 37 37 37 37 37 37 37 37 37 37 ...
## $ var_accel_dumbbell : num NA NA NA NA NA NA NA NA NA NA NA ...
## $ avg_roll_dumbbell : num NA NA NA NA NA NA NA NA NA NA NA ...
## $ stddev_roll_dumbbell : num NA NA NA NA NA NA NA NA NA NA NA ...
## $ var_roll_dumbbell : num NA NA NA NA NA NA NA NA NA NA NA ...
## $ avg_pitch_dumbbell : num NA NA NA NA NA NA NA NA NA NA NA ...
## $ stddev_pitch_dumbbell : num NA NA NA NA NA NA NA NA NA NA NA ...
## $ var_pitch_dumbbell : num NA NA NA NA NA NA NA NA NA NA NA ...
## $ avg_yaw_dumbbell : num NA NA NA NA NA NA NA NA NA NA NA ...
## $ stddev_yaw_dumbbell : num NA NA NA NA NA NA NA NA NA NA NA ...
## $ var_yaw_dumbbell : num NA NA NA NA NA NA NA NA NA NA NA ...
## $ 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 ...
## $ kurtosis_roll_forearm : Factor w/ 322 levels "", "-0.0227", "-0.0359", ...: 1 1 1 1 1 1 1 1 1 1 ...
## $ kurtosis_pitch_forearm : Factor w/ 323 levels "", "-0.0073", "-0.0442", ...: 1 1 1 1 1 1 1 1 1 1 ...
## $ kurtosis_yaw_forearm : Factor w/ 2 levels "", "#DIV/0!": 1 1 1 1 1 1 1 1 1 1 ...
## $ skewness_roll_forearm : Factor w/ 323 levels "", "-0.0004", "-0.0013", ...: 1 1 1 1 1 1 1 1 1 1 ...
## $ skewness_pitch_forearm : Factor w/ 319 levels "", "-0.0113", "-0.0131", ...: 1 1 1 1 1 1 1 1 1 1 ...
## $ skewness_yaw_forearm : Factor w/ 2 levels "", "#DIV/0!": 1 1 1 1 1 1 1 1 1 1 ...
## $ max_roll_forearm : num NA NA NA NA NA NA NA NA NA NA NA ...
## $ max_pitch_forearm : num NA NA NA NA NA NA NA NA NA NA NA ...
## $ max_yaw_forearm : Factor w/ 45 levels "", "-0.1", "-0.2", ...: 1 1 1 1 1 1 1 1 1 1 ...
## $ min_roll_forearm : num NA NA NA NA NA NA NA NA NA NA NA ...
## $ min_pitch_forearm : num NA NA NA NA NA NA NA NA NA NA NA ...
## $ min_yaw_forearm : Factor w/ 45 levels "", "-0.1", "-0.2", ...: 1 1 1 1 1 1 1 1 1 1 ...
## $ amplitude_roll_forearm : num NA NA NA NA NA NA NA NA NA NA NA ...
## $ amplitude_pitch_forearm : num NA NA NA NA NA NA NA NA NA NA NA ...
## $ amplitude_yaw_forearm : Factor w/ 3 levels "", "#DIV/0!", "0.00": 1 1 1 1 1 1 1 1 1 1 ...
## $ total_accel_forearm : int 36 36 36 36 36 36 36 36 36 36 ...
## $ var_accel_forearm : num NA NA NA NA NA NA NA NA NA NA NA ...
## $ avg_roll_forearm : num NA NA NA NA NA NA NA NA NA NA NA ...

```

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## $ stddev_roll_forearm : num NA NA NA NA NA NA NA NA NA NA ...
## $ var_roll_forearm : num NA NA NA NA NA NA NA NA NA NA ...
## $ avg_pitch_forearm : num NA NA NA NA NA NA NA NA NA NA ...
## $ stddev_pitch_forearm : num NA NA NA NA NA NA NA NA NA NA ...
## $ var_pitch_forearm : num NA NA NA NA NA NA NA NA NA NA ...
## $ avg_yaw_forearm : num NA NA NA NA NA NA NA NA NA NA ...
## $ stddev_yaw_forearm : num NA NA NA NA NA NA NA NA NA NA ...
## $ var_yaw_forearm : num NA NA NA NA NA NA NA NA NA NA ...
## $ gyros_forearm_x : num 0.03 0.02 0.03 0.02 0.02 0.02 0.02 0.02 0.03 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 ...
```

```
summary(data.training)
```

```
##           X           user_name raw_timestamp_part_1 raw_timestamp_part_2
## Min.      :    1      adelmo :3892      Min.      :1.322e+09      Min.      :   294
## 1st Qu.: 4906      carlitos:3112      1st Qu.:1.323e+09      1st Qu.:252912
## Median : 9812      charles :3536      Median :1.323e+09      Median :496380
## Mean    : 9812      eurico  :3070      Mean    :1.323e+09      Mean    :500656
## 3rd Qu.:14717      jeremy   :3402      3rd Qu.:1.323e+09      3rd Qu.:751891
## Max.    :19622      pedro    :2610      Max.    :1.323e+09      Max.    :998801
##
##           cvtd_timestamp new_window num_window roll_belt
## 28/11/2011 14:14: 1498 no :19216      Min.      : 1.0      Min.      : -28.90
## 05/12/2011 11:24: 1497 yes: 406      1st Qu.:222.0      1st Qu.: 1.10
## 30/11/2011 17:11: 1440              Median :424.0      Median :113.00
## 05/12/2011 11:25: 1425              Mean    :430.6      Mean    : 64.41
## 02/12/2011 14:57: 1380              3rd Qu.:644.0      3rd Qu.:123.00
## 02/12/2011 13:34: 1375              Max.    :864.0      Max.    :162.00
## (Other)           :11007
##           pitch_belt      yaw_belt      total_accel_belt kurtosis_roll_belt
## Min.      : -55.8000      Min.      : -180.00      Min.      : 0.00      :19216
## 1st Qu.: 1.7600      1st Qu.: -88.30      1st Qu.: 3.00      #DIV/0! : 10
## Median : 5.2800      Median : -13.00      Median :17.00      -1.908453: 2
## Mean    : 0.3053      Mean    : -11.21      Mean    :11.31      -0.016850: 1
## 3rd Qu.: 14.9000      3rd Qu.: 12.90      3rd Qu.:18.00      -0.021024: 1
## Max.    : 60.3000      Max.    : 179.00      Max.    :29.00      -0.025513: 1
## (Other)           : 391
## kurtosis_picth_belt kurtosis_yaw_belt skewness_roll_belt
## :19216 :19216 :19216
## #DIV/0! : 32 #DIV/0!: 406 #DIV/0! : 9
## 47.000000: 4 0.000000 : 4
## -0.150950: 3 0.422463 : 2
## -0.684748: 3 -0.003095: 1
## -1.750749: 3 -0.010002: 1
## (Other) : 361 (Other) : 389
## skewness_roll_belt.1 skewness_yaw_belt max_roll_belt max_picth_belt
```

```

##          :19216          :19216      Min.   :-94.300   Min.    : 3.00
## #DIV/0!  :   32      #DIV/0! :  406      1st Qu.: -88.000   1st Qu.: 5.00
## 0.000000 :    4          Median :  -5.100   Median :18.00
## -2.156553:    3          Mean   :  -6.667   Mean   :12.92
## -3.072669:    3          3rd Qu.: 18.500   3rd Qu.:19.00
## -6.324555:    3          Max.    :180.000   Max.    :30.00
## (Other)  :  361          NA's    :19216   NA's    :19216
## max_yaw_belt min_roll_belt min_pitch_belt min_yaw_belt
##          :19216 Min.    :-180.00 Min.    : 0.00          :19216
## -1.1      :   30 1st Qu.: -88.40 1st Qu.: 3.00 -1.1      :   30
## -1.4      :   29 Median :  -7.85 Median :16.00 -1.4      :   29
## -1.2      :   26 Mean     : -10.44 Mean   :10.76 -1.2      :   26
## -0.9      :   24 3rd Qu.:  9.05 3rd Qu.:17.00 -0.9      :   24
## -1.3      :   22 Max.     : 173.00 Max.    :23.00 -1.3      :   22
## (Other):  275 NA's    :19216   NA's    :19216 (Other):  275
## amplitude_roll_belt amplitude_pitch_belt amplitude_yaw_belt
## Min.    : 0.000 Min.    : 0.000          :19216
## 1st Qu.: 0.300 1st Qu.: 1.000      #DIV/0! :   10
## Median : 1.000 Median : 1.000      0.00    :   12
## Mean    : 3.769 Mean    : 2.167      0.0000  :  384
## 3rd Qu.: 2.083 3rd Qu.: 2.000
## Max.    :360.000 Max.    :12.000
## NA's    :19216 NA's    :19216
## var_total_accel_belt avg_roll_belt stddev_roll_belt var_roll_belt
## Min.    : 0.000 Min.    :-27.40 Min.    : 0.000 Min.    : 0.000
## 1st Qu.: 0.100 1st Qu.:  1.10 1st Qu.: 0.200 1st Qu.: 0.000
## Median : 0.200 Median :116.35 Median : 0.400 Median : 0.100
## Mean    : 0.926 Mean    : 68.06 Mean    : 1.337 Mean    : 7.699
## 3rd Qu.: 0.300 3rd Qu.:123.38 3rd Qu.: 0.700 3rd Qu.: 0.500
## Max.    :16.500 Max.    :157.40 Max.    :14.200 Max.    :200.700
## NA's    :19216 NA's    :19216 NA's    :19216 NA's    :19216
## avg_pitch_belt stddev_pitch_belt var_pitch_belt avg_yaw_belt
## Min.    :-51.400 Min.    :0.000 Min.    : 0.000 Min.    :-138.300
## 1st Qu.:  2.025 1st Qu.:0.200 1st Qu.: 0.000 1st Qu.: -88.175
## Median :  5.200 Median :0.400 Median : 0.100 Median :  -6.550
## Mean    :  0.520 Mean    :0.603 Mean    : 0.766 Mean    : -8.831
## 3rd Qu.: 15.775 3rd Qu.:0.700 3rd Qu.: 0.500 3rd Qu.: 14.125
## Max.    : 59.700 Max.    :4.000 Max.    :16.200 Max.    : 173.500
## NA's    :19216 NA's    :19216 NA's    :19216 NA's    :19216
## stddev_yaw_belt var_yaw_belt gyros_belt_x
## Min.    : 0.000 Min.    :  0.000 Min.    :-1.040000
## 1st Qu.: 0.100 1st Qu.:  0.010 1st Qu.: -0.030000
## Median : 0.300 Median :  0.090 Median : 0.030000
## Mean    : 1.341 Mean    : 107.487 Mean    :-0.005592
## 3rd Qu.: 0.700 3rd Qu.:  0.475 3rd Qu.: 0.110000
## Max.    :176.600 Max.    :31183.240 Max.    : 2.220000
## NA's    :19216 NA's    :19216
## gyros_belt_y gyros_belt_z accel_belt_x accel_belt_y
## Min.    :-0.64000 Min.    :-1.4600 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    : 0.03959 Mean    : -0.1305 Mean    :  -5.595 Mean    : 30.15
## 3rd Qu.: 0.11000 3rd Qu.: -0.0200 3rd Qu.:  -5.000 3rd Qu.: 61.00
## Max.    : 0.64000 Max.    :  1.6200 Max.    :  85.000 Max.    :164.00

```

```

##
##  accel_belt_z      magnet_belt_x  magnet_belt_y  magnet_belt_z
##  Min.   :-275.00    Min.   :-52.0    Min.   :354.0    Min.   :-623.0
##  1st Qu.: -162.00    1st Qu.:  9.0    1st Qu.:581.0    1st Qu.: -375.0
##  Median : -152.00    Median : 35.0    Median :601.0    Median : -320.0
##  Mean   :  -72.59    Mean   : 55.6    Mean   :593.7    Mean   : -345.5
##  3rd Qu.:  27.00    3rd Qu.: 59.0    3rd Qu.:610.0    3rd Qu.: -306.0
##  Max.    : 105.00    Max.    :485.0    Max.    :673.0    Max.    : 293.0
##
##      roll_arm      pitch_arm      yaw_arm      total_accel_arm
##  Min.   :-180.00    Min.   :-88.800    Min.   :-180.0000    Min.   : 1.00
##  1st Qu.: -31.77    1st Qu.: -25.900    1st Qu.: -43.1000    1st Qu.:17.00
##  Median :  0.00    Median :  0.000    Median :  0.0000    Median :27.00
##  Mean   :  17.83    Mean   : -4.612    Mean   : -0.6188    Mean   :25.51
##  3rd Qu.:  77.30    3rd Qu.: 11.200    3rd Qu.: 45.8750    3rd Qu.:33.00
##  Max.    : 180.00    Max.    : 88.500    Max.    : 180.0000    Max.    :66.00
##
##  var_accel_arm      avg_roll_arm      stddev_roll_arm      var_roll_arm
##  Min.   :  0.00    Min.   :-166.67    Min.   :  0.000    Min.   :  0.000
##  1st Qu.:  9.03    1st Qu.: -38.37    1st Qu.:  1.376    1st Qu.:  1.898
##  Median : 40.61    Median :  0.00    Median :  5.702    Median : 32.517
##  Mean   : 53.23    Mean   : 12.68    Mean   : 11.201    Mean   : 417.264
##  3rd Qu.: 75.62    3rd Qu.: 76.33    3rd Qu.: 14.921    3rd Qu.: 222.647
##  Max.    :331.70    Max.    : 163.33    Max.    :161.964    Max.    :26232.208
##  NA's    :19216    NA's    :19216    NA's    :19216    NA's    :19216
##  avg_pitch_arm      stddev_pitch_arm      var_pitch_arm      avg_yaw_arm
##  Min.   :-81.773    Min.   : 0.000    Min.   :  0.000    Min.   :-173.440
##  1st Qu.: -22.770    1st Qu.: 1.642    1st Qu.:  2.697    1st Qu.: -29.198
##  Median :  0.000    Median : 8.133    Median : 66.146    Median :  0.000
##  Mean   : -4.901    Mean   :10.383    Mean   : 195.864    Mean   :  2.359
##  3rd Qu.:  8.277    3rd Qu.:16.327    3rd Qu.: 266.576    3rd Qu.: 38.185
##  Max.    : 75.659    Max.    :43.412    Max.    :1884.565    Max.    : 152.000
##  NA's    :19216    NA's    :19216    NA's    :19216    NA's    :19216
##  stddev_yaw_arm      var_yaw_arm      gyros_arm_x
##  Min.   :  0.000    Min.   :  0.000    Min.   : -6.37000
##  1st Qu.:  2.577    1st Qu.:  6.642    1st Qu.: -1.33000
##  Median : 16.682    Median : 278.309    Median : 0.08000
##  Mean   : 22.270    Mean   :1055.933    Mean   : 0.04277
##  3rd Qu.: 35.984    3rd Qu.:1294.850    3rd Qu.: 1.57000
##  Max.    :177.044    Max.    :31344.568    Max.    : 4.87000
##  NA's    :19216    NA's    :19216
##  gyros_arm_y      gyros_arm_z      accel_arm_x      accel_arm_y
##  Min.   :-3.4400    Min.   :-2.3300    Min.   : -404.00    Min.   : -318.0
##  1st Qu.: -0.8000    1st Qu.: -0.0700    1st Qu.: -242.00    1st Qu.: -54.0
##  Median : -0.2400    Median : 0.2300    Median : -44.00    Median : 14.0
##  Mean   : -0.2571    Mean   : 0.2695    Mean   : -60.24    Mean   : 32.6
##  3rd Qu.: 0.1400    3rd Qu.: 0.7200    3rd Qu.: 84.00    3rd Qu.: 139.0
##  Max.    : 2.8400    Max.    : 3.0200    Max.    : 437.00    Max.    : 308.0
##
##  accel_arm_z      magnet_arm_x      magnet_arm_y      magnet_arm_z
##  Min.   :-636.00    Min.   :-584.0    Min.   : -392.0    Min.   : -597.0
##  1st Qu.: -143.00    1st Qu.: -300.0    1st Qu.:  -9.0    1st Qu.: 131.2
##  Median : -47.00    Median : 289.0    Median : 202.0    Median : 444.0
##  Mean   : -71.25    Mean   : 191.7    Mean   : 156.6    Mean   : 306.5

```



```

## 3rd Qu.: 23.00 3rd Qu.: 637.0 3rd Qu.: 323.0 3rd Qu.: 545.0
## Max. : 292.00 Max. : 782.0 Max. : 583.0 Max. : 694.0
##
## kurtosis_roll_arm kurtosis_picth_arm kurtosis_yaw_arm skewness_roll_arm
## :19216 :19216 :19216 :19216
## #DIV/0! : 78 #DIV/0! : 80 #DIV/0! : 11 #DIV/0! : 77
## -0.02438: 1 -0.00484: 1 0.55844 : 2 -0.00051: 1
## -0.04190: 1 -0.01311: 1 0.65132 : 2 -0.00696: 1
## -0.05051: 1 -0.02967: 1 -0.01548: 1 -0.01884: 1
## -0.05695: 1 -0.07394: 1 -0.01749: 1 -0.03359: 1
## (Other) : 324 (Other) : 322 (Other) : 389 (Other) : 325
## skewness_pitch_arm skewness_yaw_arm max_roll_arm max_picth_arm
## :19216 :19216 Min. : -73.100 Min. : -173.000
## #DIV/0! : 80 #DIV/0! : 11 1st Qu.: -0.175 1st Qu.: -1.975
## -0.00184: 1 -1.62032: 2 Median : 4.950 Median : 23.250
## -0.01185: 1 0.55053 : 2 Mean : 11.236 Mean : 35.751
## -0.01247: 1 -0.00311: 1 3rd Qu.: 26.775 3rd Qu.: 95.975
## -0.02063: 1 -0.00562: 1 Max. : 85.500 Max. : 180.000
## (Other) : 322 (Other) : 389 NA's :19216 NA's :19216
## max_yaw_arm min_roll_arm min_pitch_arm min_yaw_arm
## Min. : 4.00 Min. : -89.10 Min. : -180.00 Min. : 1.00
## 1st Qu.:29.00 1st Qu.: -41.98 1st Qu.: -72.62 1st Qu.: 8.00
## Median :34.00 Median : -22.45 Median : -33.85 Median :13.00
## Mean :35.46 Mean : -21.22 Mean : -33.92 Mean :14.66
## 3rd Qu.:41.00 3rd Qu.: 0.00 3rd Qu.: 0.00 3rd Qu.:19.00
## Max. :65.00 Max. : 66.40 Max. : 152.00 Max. :38.00
## NA's :19216 NA's :19216 NA's :19216 NA's :19216
## amplitude_roll_arm amplitude_pitch_arm amplitude_yaw_arm
## Min. : 0.000 Min. : 0.000 Min. : 0.00
## 1st Qu.: 5.425 1st Qu.: 9.925 1st Qu.:13.00
## Median : 28.450 Median : 54.900 Median :22.00
## Mean : 32.452 Mean : 69.677 Mean :20.79
## 3rd Qu.: 50.960 3rd Qu.:115.175 3rd Qu.:28.75
## Max. :119.500 Max. :360.000 Max. :52.00
## NA's :19216 NA's :19216 NA's :19216
## roll_dumbbell pitch_dumbbell yaw_dumbbell
## Min. : -153.71 Min. : -149.59 Min. : -150.871
## 1st Qu.: -18.49 1st Qu.: -40.89 1st Qu.: -77.644
## Median : 48.17 Median : -20.96 Median : -3.324
## Mean : 23.84 Mean : -10.78 Mean : 1.674
## 3rd Qu.: 67.61 3rd Qu.: 17.50 3rd Qu.: 79.643
## Max. : 153.55 Max. : 149.40 Max. : 154.952
##
## kurtosis_roll_dumbbell kurtosis_picth_dumbbell kurtosis_yaw_dumbbell
## :19216 :19216 :19216
## #DIV/0! : 5 -0.5464: 2 #DIV/0! : 406
## -0.2583: 2 -0.9334: 2
## -0.3705: 2 -2.0833: 2
## -0.5855: 2 -2.0851: 2
## -2.0851: 2 -2.0889: 2
## (Other): 393 (Other): 396
## skewness_roll_dumbbell skewness_pitch_dumbbell skewness_yaw_dumbbell
## :19216 :19216 :19216
## #DIV/0! : 4 -0.2328: 2 #DIV/0! : 406

```

```

## -0.9324:      2          -0.3521:      2
## 0.1110 :      2          -0.7036:      2
## 1.0312 :      2          0.1090 :      2
## -0.0082:      1          1.0326 :      2
## (Other): 395          (Other): 396
## max_roll_dumbbell max_pitch_dumbbell max_yaw_dumbbell min_roll_dumbbell
## Min.      :-70.10      Min.      :-112.90      :19216      Min.      :-149.60
## 1st Qu.: -27.15      1st Qu.: -66.70      -0.6      : 20      1st Qu.: -59.67
## Median : 14.85      Median : 40.05      0.2      : 19      Median : -43.55
## Mean   : 13.76      Mean   : 32.75      -0.8      : 18      Mean   : -41.24
## 3rd Qu.: 50.58      3rd Qu.: 133.22      -0.3      : 16      3rd Qu.: -25.20
## Max.    :137.00      Max.    : 155.00      -0.2      : 15      Max.    : 73.20
## NA's     :19216      NA's     :19216      (Other): 318      NA's     :19216
## min_pitch_dumbbell min_yaw_dumbbell amplitude_roll_dumbbell
## Min.      :-147.00      :19216      Min.      : 0.00
## 1st Qu.: -91.80      -0.6      : 20      1st Qu.: 14.97
## Median : -66.15      0.2      : 19      Median : 35.05
## Mean   : -33.18      -0.8      : 18      Mean   : 55.00
## 3rd Qu.: 21.20      -0.3      : 16      3rd Qu.: 81.04
## Max.    : 120.90      -0.2      : 15      Max.    :256.48
## NA's     :19216      (Other): 318      NA's     :19216
## amplitude_pitch_dumbbell amplitude_yaw_dumbbell total_accel_dumbbell
## Min.      : 0.00      :19216      Min.      : 0.00
## 1st Qu.: 17.06      #DIV/0!: 5      1st Qu.: 4.00
## Median : 41.73      0.00      : 401      Median :10.00
## Mean   : 65.93      Mean   :13.72
## 3rd Qu.: 99.55      3rd Qu.:19.00
## Max.    :273.59      Max.    :58.00
## NA's     :19216
## var_accel_dumbbell avg_roll_dumbbell stddev_roll_dumbbell
## Min.      : 0.000      Min.      :-128.96      Min.      : 0.000
## 1st Qu.: 0.378      1st Qu.: -12.33      1st Qu.: 4.639
## Median : 1.000      Median : 48.23      Median : 12.204
## Mean   : 4.388      Mean   : 23.86      Mean   : 20.761
## 3rd Qu.: 3.434      3rd Qu.: 64.37      3rd Qu.: 26.356
## Max.    :230.428      Max.    : 125.99      Max.    :123.778
## NA's     :19216      NA's     :19216      NA's     :19216
## var_roll_dumbbell avg_pitch_dumbbell stddev_pitch_dumbbell
## Min.      : 0.00      Min.      :-70.73      Min.      : 0.000
## 1st Qu.: 21.52      1st Qu.: -42.00      1st Qu.: 3.482
## Median : 148.95      Median : -19.91      Median : 8.089
## Mean   : 1020.27      Mean   : -12.33      Mean   :13.147
## 3rd Qu.: 694.65      3rd Qu.: 13.21      3rd Qu.:19.238
## Max.    :15321.01      Max.    : 94.28      Max.    :82.680
## NA's     :19216      NA's     :19216      NA's     :19216
## var_pitch_dumbbell avg_yaw_dumbbell stddev_yaw_dumbbell
## Min.      : 0.00      Min.      :-117.950      Min.      : 0.000
## 1st Qu.: 12.12      1st Qu.: -76.696      1st Qu.: 3.885
## Median : 65.44      Median : -4.505      Median : 10.264
## Mean   : 350.31      Mean   : 0.202      Mean   : 16.647
## 3rd Qu.: 370.11      3rd Qu.: 71.234      3rd Qu.: 24.674
## Max.    :6836.02      Max.    : 134.905      Max.    :107.088
## NA's     :19216      NA's     :19216      NA's     :19216
## var_yaw_dumbbell gyros_dumbbell_x gyros_dumbbell_y

```

```

## Min.      : 0.00      Min.      :-204.0000      Min.      :-2.10000
## 1st Qu.: 15.09      1st Qu.: -0.0300      1st Qu.: -0.14000
## Median : 105.35      Median : 0.1300      Median : 0.03000
## Mean    : 589.84      Mean    : 0.1611      Mean    : 0.04606
## 3rd Qu.: 608.79      3rd Qu.: 0.3500      3rd Qu.: 0.21000
## Max.    :11467.91      Max.     : 2.2200      Max.     :52.00000
## NA's    :19216
## gyros_dumbbell_z accel_dumbbell_x accel_dumbbell_y accel_dumbbell_z
## Min.      : -2.380      Min.      :-419.00      Min.      :-189.00      Min.      :-334.00
## 1st Qu.: -0.310      1st Qu.: -50.00      1st Qu.: -8.00      1st Qu.: -142.00
## Median : -0.130      Median : -8.00      Median : 41.50      Median : -1.00
## Mean    : -0.129      Mean    : -28.62      Mean    : 52.63      Mean    : -38.32
## 3rd Qu.: 0.030      3rd Qu.: 11.00      3rd Qu.: 111.00      3rd Qu.: 38.00
## Max.    :317.000      Max.     : 235.00      Max.     : 315.00      Max.     : 318.00
##
## magnet_dumbbell_x magnet_dumbbell_y magnet_dumbbell_z roll_forearm
## Min.      : -643.0      Min.      :-3600      Min.      :-262.00      Min.      :-180.0000
## 1st Qu.: -535.0      1st Qu.: 231      1st Qu.: -45.00      1st Qu.: -0.7375
## Median : -479.0      Median : 311      Median : 13.00      Median : 21.7000
## Mean    : -328.5      Mean    : 221      Mean    : 46.05      Mean    : 33.8265
## 3rd Qu.: -304.0      3rd Qu.: 390      3rd Qu.: 95.00      3rd Qu.: 140.0000
## Max.    : 592.0      Max.     : 633      Max.     : 452.00      Max.     : 180.0000
##
## pitch_forearm      yaw_forearm      kurtosis_roll_forearm
## Min.      : -72.50      Min.      :-180.00      :19216
## 1st Qu.: 0.00      1st Qu.: -68.60      #DIV/0!: 84
## Median : 9.24      Median : 0.00      -0.8079: 2
## Mean    : 10.71      Mean    : 19.21      -0.9169: 2
## 3rd Qu.: 28.40      3rd Qu.: 110.00      -0.0227: 1
## Max.    : 89.80      Max.     : 180.00      -0.0359: 1
##                                     (Other): 316
## kurtosis_picth_forearm kurtosis_yaw_forearm skewness_roll_forearm
## :19216 :19216 :19216
## #DIV/0!: 85 #DIV/0!: 406 #DIV/0!: 83
## -0.0073: 1 -0.1912: 2
## -0.0442: 1 -0.4126: 2
## -0.0489: 1 -0.0004: 1
## -0.0523: 1 -0.0013: 1
## (Other): 317 (Other): 317
## skewness_pitch_forearm skewness_yaw_forearm max_roll_forearm
## :19216 :19216 Min.      :-66.60
## #DIV/0!: 85 #DIV/0!: 406 1st Qu.: 0.00
## 0.0000 : 4 Median : 26.80
## -0.6992: 2 Mean : 24.49
## -0.0113: 1 3rd Qu.: 45.95
## -0.0131: 1 Max. : 89.80
## (Other): 313 NA's :19216
## max_picth_forearm max_yaw_forearm min_roll_forearm min_pitch_forearm
## Min.      : -151.00 :19216 Min.      :-72.500      Min.      :-180.00
## 1st Qu.: 0.00 #DIV/0!: 84 1st Qu.: -6.075      1st Qu.: -175.00
## Median : 113.00 -1.2 : 32 Median : 0.000      Median : -61.00
## Mean : 81.49 -1.3 : 31 Mean : -0.167      Mean : -57.57
## 3rd Qu.: 174.75 -1.4 : 24 3rd Qu.: 12.075      3rd Qu.: 0.00
## Max. : 180.00 -1.5 : 24 Max. : 62.100      Max. : 167.00

```

```

## NA's :19216 (Other): 211 NA's :19216 NA's :19216
## min_yaw_forearm amplitude_roll_forearm amplitude_pitch_forearm
## :19216 Min. : 0.000 Min. : 0.0
## #DIV/0!: 84 1st Qu.: 1.125 1st Qu.: 2.0
## -1.2 : 32 Median : 17.770 Median : 83.7
## -1.3 : 31 Mean : 24.653 Mean :139.1
## -1.4 : 24 3rd Qu.: 39.875 3rd Qu.:350.0
## -1.5 : 24 Max. :126.000 Max. :360.0
## (Other): 211 NA's :19216 NA's :19216
## amplitude_yaw_forearm total_accel_forearm var_accel_forearm
## :19216 Min. : 0.00 Min. : 0.000
## #DIV/0!: 84 1st Qu.: 29.00 1st Qu.: 6.759
## 0.00 : 322 Median : 36.00 Median : 21.165
## Mean : 34.72 Mean : 33.502
## 3rd Qu.: 41.00 3rd Qu.: 51.240
## Max. :108.00 Max. :172.606
## NA's :19216
## avg_roll_forearm stddev_roll_forearm var_roll_forearm
## Min. : -177.234 Min. : 0.000 Min. : 0.00
## 1st Qu.: -0.909 1st Qu.: 0.428 1st Qu.: 0.18
## Median : 11.172 Median : 8.030 Median : 64.48
## Mean : 33.165 Mean : 41.986 Mean : 5274.10
## 3rd Qu.: 107.132 3rd Qu.: 85.373 3rd Qu.: 7289.08
## Max. : 177.256 Max. :179.171 Max. :32102.24
## NA's :19216 NA's :19216 NA's :19216
## avg_pitch_forearm stddev_pitch_forearm var_pitch_forearm
## Min. : -68.17 Min. : 0.000 Min. : 0.000
## 1st Qu.: 0.00 1st Qu.: 0.336 1st Qu.: 0.113
## Median : 12.02 Median : 5.516 Median : 30.425
## Mean : 11.79 Mean : 7.977 Mean : 139.593
## 3rd Qu.: 28.48 3rd Qu.:12.866 3rd Qu.: 165.532
## Max. : 72.09 Max. :47.745 Max. :2279.617
## NA's :19216 NA's :19216 NA's :19216
## avg_yaw_forearm stddev_yaw_forearm var_yaw_forearm gyros_forearm_x
## Min. : -155.06 Min. : 0.000 Min. : 0.00 Min. : -22.000
## 1st Qu.: -26.26 1st Qu.: 0.524 1st Qu.: 0.27 1st Qu.: -0.220
## Median : 0.00 Median : 24.743 Median : 612.21 Median : 0.050
## Mean : 18.00 Mean : 44.854 Mean : 4639.85 Mean : 0.158
## 3rd Qu.: 85.79 3rd Qu.: 85.817 3rd Qu.: 7368.41 3rd Qu.: 0.560
## Max. : 169.24 Max. :197.508 Max. :39009.33 Max. : 3.970
## NA's :19216 NA's :19216 NA's :19216
## 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
##
##
```

---

## Appendix #2

### Testing set inspection

```
# Instant data touching
levels(data.testing$user_name)
```

```
## [1] "adelmo" "carlitos" "charles" "eurico" "jeremy" "pedro"
```

```
data.testing$problem_id
```

```
## [1] 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
```

```
str(data.testing, list.len = 999)
```

```
## '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 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 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 ...
## $ 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 ...
## $ 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 ...
## $ amplitude_pitch_dumbbell : logi NA NA NA NA NA NA ...
## $ amplitude_yaw_dumbbell : logi NA NA NA NA NA NA ...
## $ total_accel_dumbbell : int 9 31 29 18 4 29 29 29 3 2 ...
## $ var_accel_dumbbell : logi NA NA NA NA NA NA ...
## $ avg_roll_dumbbell : logi NA NA NA NA NA NA ...
## $ stddev_roll_dumbbell : logi NA NA NA NA NA NA ...
## $ var_roll_dumbbell : logi NA NA NA NA NA NA ...
## $ avg_pitch_dumbbell : logi NA NA NA NA NA NA ...
## $ stddev_pitch_dumbbell : logi NA NA NA NA NA NA ...
## $ var_pitch_dumbbell : logi NA NA NA NA NA NA ...
## $ avg_yaw_dumbbell : logi NA NA NA NA NA NA ...
## $ stddev_yaw_dumbbell : logi NA NA NA NA NA NA ...
## $ var_yaw_dumbbell : logi NA NA NA NA NA NA ...
## $ 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 ...
## $ kurtosis_roll_forearm : logi NA NA NA NA NA NA ...
## $ kurtosis_pitch_forearm : logi NA NA NA NA NA NA ...
## $ kurtosis_yaw_forearm : logi NA NA NA NA NA NA ...
## $ skewness_roll_forearm : logi NA NA NA NA NA NA ...
## $ skewness_pitch_forearm : logi NA NA NA NA NA NA ...
## $ skewness_yaw_forearm : logi NA NA NA NA NA NA ...
## $ max_roll_forearm : logi NA NA NA NA NA NA ...
## $ max_pitch_forearm : logi NA NA NA NA NA NA ...
## $ max_yaw_forearm : logi NA NA NA NA NA NA ...
## $ min_roll_forearm : logi NA NA NA NA NA NA ...
## $ min_pitch_forearm : logi NA NA NA NA NA NA ...
## $ min_yaw_forearm : logi NA NA NA NA NA NA ...
## $ amplitude_roll_forearm : logi NA NA NA NA NA NA ...
## $ amplitude_pitch_forearm : logi NA NA NA NA NA NA ...
## $ amplitude_yaw_forearm : logi NA NA NA NA NA NA ...
## $ total_accel_forearm : int 33 39 34 43 24 43 32 47 36 24 ...
## $ var_accel_forearm : logi NA NA NA NA NA NA ...
## $ avg_roll_forearm : logi NA NA NA NA NA NA ...

```



```
## $ stddev_roll_forearm      : logi  NA NA NA NA NA NA ...
## $ var_roll_forearm         : logi  NA NA NA NA NA NA ...
## $ avg_pitch_forearm        : logi  NA NA NA NA NA NA ...
## $ stddev_pitch_forearm     : logi  NA NA NA NA NA NA ...
## $ var_pitch_forearm        : logi  NA NA NA NA NA NA ...
## $ avg_yaw_forearm          : logi  NA NA NA NA NA NA ...
## $ stddev_yaw_forearm       : logi  NA NA NA NA NA NA ...
## $ var_yaw_forearm          : logi  NA NA NA NA NA NA ...
## $ 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 ...
```

```
summary(data.testing)
```

```
##           X           user_name raw_timestamp_part_1 raw_timestamp_part_2
## Min.      : 1.00      adelmo :1   Min.      :1.322e+09   Min.      : 36553
## 1st Qu.: 5.75      carlitos:3   1st Qu.:1.323e+09   1st Qu.:268655
## Median :10.50     charles :1   Median :1.323e+09   Median :530706
## Mean    :10.50     eurico  :4   Mean    :1.323e+09   Mean    :512167
## 3rd Qu.:15.25     jeremy   :8   3rd Qu.:1.323e+09   3rd Qu.:787738
## Max.    :20.00     pedro    :3   Max.    :1.323e+09   Max.    :920315
##
##           cvtd_timestamp new_window  num_window  roll_belt
## 30/11/2011 17:11:4      no:20      Min.      : 48.0   Min.      : -5.9200
## 05/12/2011 11:24:3                      1st Qu.:250.0   1st Qu.: 0.9075
## 30/11/2011 17:12:3                      Median :384.5   Median : 1.1100
## 05/12/2011 14:23:2                      Mean    :379.6   Mean    : 31.3055
## 28/11/2011 14:14:2                      3rd Qu.:467.0   3rd Qu.: 32.5050
## 02/12/2011 13:33:1                      Max.      :859.0   Max.      :129.0000
## (Other)           :5
##           pitch_belt      yaw_belt      total_accel_belt kurtosis_roll_belt
## Min.      : -41.600   Min.      : -93.70   Min.      : 2.00   Mode:logical
## 1st Qu.: 3.013     1st Qu.: -88.62   1st Qu.: 3.00   NA's:20
## Median : 4.655     Median : -87.85   Median : 4.00
## Mean    : 5.824     Mean    : -59.30   Mean    : 7.55
## 3rd Qu.: 6.135     3rd Qu.: -63.50   3rd Qu.: 8.00
## Max.    : 27.800     Max.    :162.00   Max.    :21.00
##
##           kurtosis_picth_belt kurtosis_yaw_belt skewness_roll_belt
## Mode:logical      Mode:logical      Mode:logical
## NA's:20           NA's:20           NA's:20
##
##
##
##
## skewness_roll_belt.1 skewness_yaw_belt max_roll_belt  max_picth_belt
```

```

## Mode:logical      Mode:logical      Mode:logical      Mode:logical
## NA's:20           NA's:20           NA's:20           NA's:20
##
##
##
##
## max_yaw_belt      min_roll_belt      min_pitch_belt      min_yaw_belt
## Mode:logical      Mode:logical      Mode:logical      Mode:logical
## NA's:20           NA's:20           NA's:20           NA's:20
##
##
##
##
## amplitude_roll_belt amplitude_pitch_belt amplitude_yaw_belt
## Mode:logical      Mode:logical      Mode:logical
## NA's:20           NA's:20           NA's:20
##
##
##
##
## var_total_accel_belt avg_roll_belt      stddev_roll_belt      var_roll_belt
## Mode:logical      Mode:logical      Mode:logical      Mode:logical
## NA's:20           NA's:20           NA's:20           NA's:20
##
##
##
##
## avg_pitch_belt      stddev_pitch_belt      var_pitch_belt      avg_yaw_belt
## Mode:logical      Mode:logical      Mode:logical      Mode:logical
## NA's:20           NA's:20           NA's:20           NA's:20
##
##
##
##
## stddev_yaw_belt      var_yaw_belt      gyros_belt_x      gyros_belt_y
## Mode:logical      Mode:logical      Min.      :-0.500      Min.      :-0.050
## NA's:20           NA's:20           1st Qu.: -0.070      1st Qu.: -0.005
##                               Median : 0.020      Median : 0.000
##                               Mean      :-0.045      Mean      : 0.010
##                               3rd Qu.: 0.070      3rd Qu.: 0.020
##                               Max.      : 0.240      Max.      : 0.110
##
## gyros_belt_z      accel_belt_x      accel_belt_y      accel_belt_z
## Min.      :-0.4800      Min.      :-48.00      Min.      :-16.00      Min.      :-187.00
## 1st Qu.: -0.1375      1st Qu.: -19.00      1st Qu.: 2.00      1st Qu.: -24.00
## Median : -0.0250      Median : -13.00      Median : 4.50      Median : 27.00
## Mean      :-0.1005      Mean      :-13.50      Mean      : 18.35      Mean      : -17.60
## 3rd Qu.: 0.0000      3rd Qu.: -8.75      3rd Qu.: 25.50      3rd Qu.: 38.25
## Max.      : 0.0500      Max.      : 46.00      Max.      : 72.00      Max.      : 49.00

```

```

##
## magnet_belt_x    magnet_belt_y    magnet_belt_z    roll_arm
## Min.    :-13.00    Min.    :566.0    Min.    :-426.0    Min.    :-137.00
## 1st Qu.:  5.50    1st Qu.:578.5    1st Qu.: -398.5    1st Qu.:  0.00
## Median : 33.50    Median :600.5    Median : -313.5    Median :  0.00
## Mean   : 35.15    Mean   :601.5    Mean   : -346.9    Mean   : 16.42
## 3rd Qu.: 46.25    3rd Qu.:631.2    3rd Qu.: -305.0    3rd Qu.: 71.53
## Max.   :169.00    Max.   :638.0    Max.   : -291.0    Max.   :152.00
##
##      pitch_arm      yaw_arm      total_accel_arm var_accel_arm
## Min.    :-63.800    Min.    :-167.00    Min.    : 3.00    Mode:logical
## 1st Qu.: -9.188    1st Qu.: -60.15    1st Qu.:20.25    NA's:20
## Median :  0.000    Median :  0.00    Median :29.50
## Mean   : -3.950    Mean   :  -2.80    Mean   :26.40
## 3rd Qu.:  3.465    3rd Qu.: 25.50    3rd Qu.:33.25
## Max.   : 55.000    Max.   :178.00    Max.   :44.00
##
## avg_roll_arm    stddev_roll_arm var_roll_arm    avg_pitch_arm
## Mode:logical    Mode:logical    Mode:logical    Mode:logical
## NA's:20          NA's:20          NA's:20          NA's:20
##
##
##
##
## stddev_pitch_arm var_pitch_arm    avg_yaw_arm    stddev_yaw_arm
## Mode:logical    Mode:logical    Mode:logical    Mode:logical
## NA's:20          NA's:20          NA's:20          NA's:20
##
##
##
##
## var_yaw_arm      gyros_arm_x      gyros_arm_y      gyros_arm_z
## Mode:logical    Min.    :-3.710    Min.    :-2.0900    Min.    :-0.6900
## NA's:20          1st Qu.: -0.645    1st Qu.: -0.6350    1st Qu.: -0.1800
##                  Median : 0.020    Median : -0.0400    Median : -0.0250
##                  Mean   : 0.077    Mean   : -0.1595    Mean   : 0.1205
##                  3rd Qu.: 1.248    3rd Qu.: 0.2175    3rd Qu.: 0.5650
##                  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      kurtosis_roll_arm kurtosis_pitch_arm
## Min.    :-307.0    Min.    :-499.0    Mode:logical      Mode:logical
## 1st Qu.: 205.2     1st Qu.: 403.0    NA's:20            NA's:20
## Median : 291.0     Median : 476.5
## Mean   : 239.4     Mean   : 369.8

```

```

## 3rd Qu.: 358.8    3rd Qu.: 517.0
## Max.    : 474.0    Max.    : 633.0
##
## kurtosis_yaw_arm skewness_roll_arm skewness_pitch_arm skewness_yaw_arm
## Mode:logical      Mode:logical      Mode:logical      Mode:logical
## NA's:20           NA's:20           NA's:20           NA's:20
##
##
##
##
## max_roll_arm      max_pitch_arm      max_yaw_arm      min_roll_arm
## Mode:logical      Mode:logical      Mode:logical      Mode:logical
## NA's:20           NA's:20           NA's:20           NA's:20
##
##
##
##
## min_pitch_arm     min_yaw_arm      amplitude_roll_arm amplitude_pitch_arm
## Mode:logical      Mode:logical      Mode:logical      Mode:logical
## NA's:20           NA's:20           NA's:20           NA's:20
##
##
##
##
## amplitude_yaw_arm roll_dumbbell      pitch_dumbbell      yaw_dumbbell
## Mode:logical      Min.    :-111.118    Min.    :-54.97      Min.    :-103.3200
## NA's:20           1st Qu.:  7.494    1st Qu.: -51.89     1st Qu.: -75.2809
##                   Median : 50.403    Median : -40.81     Median :  -8.2863
##                   Mean   : 33.760    Mean   : -19.47     Mean   :  -0.9385
##                   3rd Qu.: 58.129    3rd Qu.: 16.12     3rd Qu.: 55.8335
##                   Max.    : 123.984    Max.    : 96.87      Max.    : 132.2337
##
## kurtosis_roll_dumbbell kurtosis_pitch_dumbbell kurtosis_yaw_dumbbell
## Mode:logical          Mode:logical          Mode:logical
## NA's:20               NA's:20               NA's:20
##
##
##
##
## skewness_roll_dumbbell skewness_pitch_dumbbell skewness_yaw_dumbbell
## Mode:logical          Mode:logical          Mode:logical
## NA's:20               NA's:20               NA's:20
##
##
##
##
## max_roll_dumbbell max_pitch_dumbbell max_yaw_dumbbell min_roll_dumbbell
## Mode:logical      Mode:logical      Mode:logical      Mode:logical
## NA's:20           NA's:20           NA's:20           NA's:20

```

```

##
##
##
##
## min_pitch_dumbbell min_yaw_dumbbell amplitude_roll_dumbbell
## Mode:logical      Mode:logical      Mode:logical
## NA's:20           NA's:20           NA's:20
##
##
##
##
## amplitude_pitch_dumbbell amplitude_yaw_dumbbell total_accel_dumbbell
## Mode:logical      Mode:logical      Min.    : 1.0
## NA's:20           NA's:20           1st Qu.: 7.0
##                                     Median :15.5
##                                     Mean    :17.2
##                                     3rd Qu.:29.0
##                                     Max.    :31.0
##
## var_accel_dumbbell avg_roll_dumbbell stddev_roll_dumbbell
## Mode:logical      Mode:logical      Mode:logical
## NA's:20           NA's:20           NA's:20
##
##
##
##
## var_roll_dumbbell avg_pitch_dumbbell stddev_pitch_dumbbell
## Mode:logical      Mode:logical      Mode:logical
## NA's:20           NA's:20           NA's:20
##
##
##
##
## var_pitch_dumbbell avg_yaw_dumbbell stddev_yaw_dumbbell var_yaw_dumbbell
## Mode:logical      Mode:logical      Mode:logical      Mode:logical
## NA's:20           NA's:20           NA's:20           NA's:20
##
##
##
##
## gyros_dumbbell_x gyros_dumbbell_y gyros_dumbbell_z accel_dumbbell_x
## Min.    :-1.0300 Min.    :-1.1100 Min.    :-1.180 Min.    :-159.00
## 1st Qu.: 0.1600 1st Qu.: -0.2100 1st Qu.: -0.485 1st Qu.: -140.25
## Median : 0.3600 Median : 0.0150 Median : -0.280 Median : -19.00
## Mean    : 0.2690 Mean    : 0.0605 Mean    : -0.266 Mean    : -47.60
## 3rd Qu.: 0.4625 3rd Qu.: 0.1450 3rd Qu.: -0.165 3rd Qu.: 15.75
## Max.    : 1.0600 Max.    : 1.9100 Max.    : 1.100 Max.    : 185.00
##
## accel_dumbbell_y accel_dumbbell_z magnet_dumbbell_x magnet_dumbbell_y

```

```

## Min.      :-30.00    Min.      :-221.0    Min.      :-576.0    Min.      :-558.0
## 1st Qu.:   5.75    1st Qu.: -192.2    1st Qu.: -528.0    1st Qu.:  259.5
## Median :  71.50    Median :   -3.0    Median : -508.5    Median :  316.0
## Mean   :  70.55    Mean   :  -60.0    Mean   : -304.2    Mean   :  189.3
## 3rd Qu.: 151.25    3rd Qu.:   76.5    3rd Qu.: -317.0    3rd Qu.:  348.2
## Max.    : 166.00    Max.    :  100.0    Max.    :  523.0    Max.    :  403.0
##
## magnet_dumbbell_z  roll_forearm      pitch_forearm      yaw_forearm
## Min.      :-164.00    Min.      :-176.00    Min.      :-63.500    Min.      :-168.000
## 1st Qu.:  -33.00    1st Qu.:  -40.25    1st Qu.: -11.457    1st Qu.:  -93.375
## Median :   49.50    Median :   94.20    Median :   8.830    Median :  -19.250
## Mean   :   71.40    Mean   :   38.66    Mean   :   7.099    Mean   :   2.195
## 3rd Qu.:   96.25    3rd Qu.:  143.25    3rd Qu.:  28.500    3rd Qu.:  104.500
## Max.    :  368.00    Max.    :  176.00    Max.    :  59.300    Max.    :  159.000
##
## kurtosis_roll_forearm kurtosis_pitch_forearm kurtosis_yaw_forearm
## Mode:logical          Mode:logical          Mode:logical
## NA's:20                NA's:20                NA's:20
##
##
##
##
##
## skewness_roll_forearm skewness_pitch_forearm skewness_yaw_forearm
## Mode:logical          Mode:logical          Mode:logical
## NA's:20                NA's:20                NA's:20
##
##
##
##
##
## max_roll_forearm max_pitch_forearm max_yaw_forearm min_roll_forearm
## Mode:logical          Mode:logical          Mode:logical          Mode:logical
## NA's:20                NA's:20                NA's:20                NA's:20
##
##
##
##
##
## min_pitch_forearm min_yaw_forearm amplitude_roll_forearm
## Mode:logical          Mode:logical          Mode:logical
## NA's:20                NA's:20                NA's:20
##
##
##
##
##
## amplitude_pitch_forearm amplitude_yaw_forearm total_accel_forearm
## Mode:logical          Mode:logical          Min.      :21.00
## NA's:20                NA's:20                1st Qu.:24.00
##                               Median :32.50
##                               Mean   :32.05
##                               3rd Qu.:36.75
##                               Max.    :47.00

```

```

##
## var_accel_forearm avg_roll_forearm stddev_roll_forearm var_roll_forearm
## Mode:logical      Mode:logical      Mode:logical      Mode:logical
## NA's:20           NA's:20           NA's:20           NA's:20
##
##
##
##
## avg_pitch_forearm stddev_pitch_forearm var_pitch_forearm avg_yaw_forearm
## Mode:logical      Mode:logical      Mode:logical      Mode:logical
## NA's:20           NA's:20           NA's:20           NA's:20
##
##
##
##
## stddev_yaw_forearm var_yaw_forearm gyros_forearm_x  gyros_forearm_y
## Mode:logical      Mode:logical      Min.      :-1.0600 Min.      :-5.9700
## NA's:20           NA's:20           1st Qu.: -0.5850 1st Qu.: -1.2875
##                               Median : 0.0200 Median : 0.0350
##                               Mean   :-0.0200 Mean   :-0.0415
##                               3rd Qu.: 0.2925 3rd Qu.: 2.0475
##                               Max.    : 1.3800 Max.    : 4.2600
##
## gyros_forearm_z accel_forearm_x accel_forearm_y accel_forearm_z
## Min.      :-1.2600 Min.      :-212.0 Min.      :-331.0 Min.      :-282.0
## 1st Qu.: -0.0975 1st Qu.: -114.8 1st Qu.: 8.5 1st Qu.: -199.0
## Median : 0.2300 Median : 86.0 Median : 138.0 Median : -148.5
## Mean   : 0.2610 Mean   : 38.8 Mean   : 125.3 Mean   : -93.7
## 3rd Qu.: 0.7625 3rd Qu.: 166.2 3rd Qu.: 268.0 3rd Qu.: -31.0
## Max.    : 1.8000 Max.    : 232.0 Max.    : 406.0 Max.    : 179.0
##
## magnet_forearm_x magnet_forearm_y magnet_forearm_z problem_id
## Min.      :-714.0 Min.      :-787.0 Min.      :-32.0 Min.      : 1.00
## 1st Qu.: -427.2 1st Qu.: -328.8 1st Qu.: 275.2 1st Qu.: 5.75
## Median : -189.5 Median : 487.0 Median : 491.5 Median : 10.50
## Mean   : -159.2 Mean   : 191.8 Mean   : 460.2 Mean   : 10.50
## 3rd Qu.: 41.5 3rd Qu.: 720.8 3rd Qu.: 661.5 3rd Qu.: 15.25
## Max.    : 532.0 Max.    : 800.0 Max.    : 884.0 Max.    : 20.00
##

```

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