

# Practical Machine Learning - Exercise classification

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## Synopsis

Today, a large number of devices such as Jawbone Up, Nike FuelBand, and Fitbit it can collect large amount of data about personal activity relatively inexpensively.

In this project, we will try to use the data collected from accelerometers on the belt, forearm, arm, and dumbbell of 6 participants to predict the manner in which they did the exercise.

We will test different models and pick the best one to predict the class of 20 additional records.

## Data

We used and copied the 2 following data files to the current directory :

- training data : <https://d396qusza40orc.cloudfront.net/predmachlearn/pml-training.csv>

- test data : [https://d396qusza40orc.cloudfront.net/pml-testing.csv](https://d396qusza40orc.cloudfront.net/predmachlearn/pml-testing.csv)

The original data from this project comes from this source: <http://groupware.les.inf.puc-rio.br/har>.

```
# Load the R libraries
library(caret, warn.conflicts = TRUE)
library(tidyverse, warn.conflicts = TRUE)
```

## Load the Data

From a first file load and summary, we found that a the files contains “NA” and “#DIV/0!”. We will convert these values to NAs.

```
# Load the CSV files
pmlTraining <- read.csv("pml-training.csv", header=TRUE, na.strings = c("NA","", "#DIV/0!"))
pmlTesting <- read.csv("pml-testing.csv", header=TRUE, na.strings = c("NA","", "#DIV/0!"))
```

The trainData dataset contains **19622** rows and the testData dataset contains **20** rows. Each dataset contains **160** columns.

## Quick Exploratory analysis

The summary function output has been set in appendix.

```
# summary(pmlTraining)
# list the levels for the classe factor
levels(pmlTraining$classe)

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

# summarize the classe column distribution
percentage <- prop.table(table(pmlTraining$classe)) * 100
cbind('Count'=table(pmlTraining$classe), '%'=percentage)
```

```
## Count      %
## A  5580 28.43747
## B  3797 19.35073
## C  3422 17.43961
## D  3216 16.38977
## E  3607 18.38243
```

A lot of columns have a high number of NAs (> 98% of the values).

```
table(NAs=colSums(is.na(pmlTraining)))
```

```
## NAs
##      0 19216 19217 19218 19220 19221 19225 19226 19227 19248 19293 19294
##     60   67    1     1     1     4     1     4     2     2     1     1
## 19296 19299 19300 19301 19622
##      2     1     4     2     6
```

These NAs do not seem to be specific to an exercise class (ex : an exercise not using a specific devise). We will remove these columns from our predictors.

```
table(pmlTraining$classe, is.na(pmlTraining$amplitude_roll_forearm))
```

```
##
##      FALSE TRUE
## A    109 5471
## B     79 3718
## C     70 3352
## D     69 3147
## E     79 3528
```

## Clean the data

We will remove the column containing the high number of NAs, and the first 7 columns that are the experiments (user / date / ...) informations.

```
iNasColumn <- which(colSums(is.na(pmlTraining))>19000)
pmlTrainingClean <- pmlTraining[,-iNasColumn]
pmlTrainingClean <- pmlTrainingClean[,-c(1:7)]
```

## Build models

### Split the train dataset in training and validation datasets

```
# Reproducibility
set.seed(123)
# pick 80% of the rows in the original dataset
inTrain <- createDataPartition(pmlTrainingClean$classe, p=0.80, list=FALSE)
# 80% of the data to train the models
training <- pmlTrainingClean[inTrain,]
# 20% of the data for validation
validation <- pmlTrainingClean[-inTrain,]

dim(training)
```

```
## [1] 15699    53
```

## Test different models

```
nbmodels <- length(unique(modelLookup()[modelLookup()$forClass,c(1)]))
```

Caret has **190** classification models. We are going to test 5 models from the course.

We will use 5-fold cross validation.

```
trControl <- trainControl(method="cv", number=5)
metric <- "Accuracy"
```

Train different models (using the same seed each time).

```
# Tree
set.seed(123)
fit.rpart <- train(classe~., data=training, method="rpart", metric=metric, trControl=trControl)

# Random Forest
set.seed(123)
fit.rf <- train(classe~., data=training, method="rf", metric=metric, trControl=trControl)

# Boosting
set.seed(123)
fit.boosting <- train(classe~., data=training, method="gbm", metric=metric,
                     trControl=trControl, verbose=FALSE)

# Model base prediction: LDA, NB
set.seed(123)
fit.lda <- train(classe~., data=training, method="lda", metric=metric, trControl=trControl)

set.seed(123)
fit.nb <- train(classe~., data=training, method="nb", metric=metric, trControl=trControl)
```

We Compare the models using the resamples caret function.

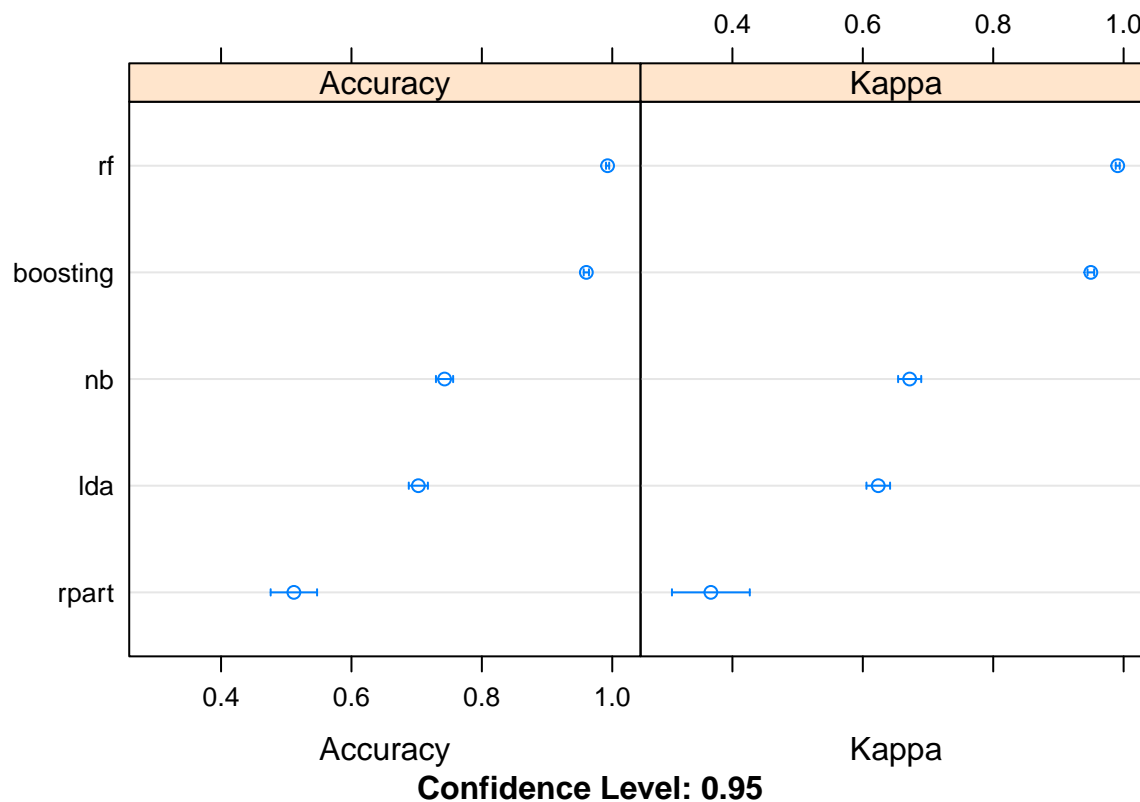
```
# Compare algorithms using the resamples caret function
results <- resamples(list(rpart=fit.rpart,
                         rf=fit.rf, boosting=fit.boosting,
                         lda=fit.lda, nb=fit.nb))

summary(results)
```

```
##
## Call:
## summary.resamples(object = results)
##
## Models: rpart, rf, boosting, lda, nb
## Number of resamples: 5
##
## Accuracy
##           Min.    1st Qu.    Median      Mean   3rd Qu.      Max. NA's
## rpart  0.4877428 0.4914013 0.4998408 0.5116952 0.5226259 0.5568652    0
## rf      0.9910800 0.9910856 0.9923591 0.9928660 0.9945825 0.9952229    0
## boosting 0.9563833 0.9592486 0.9598598 0.9602526 0.9604844 0.9652866    0
## lda     0.6864245 0.7016874 0.7021344 0.7025905 0.7029608 0.7197452    0
## nb      0.7314431 0.7347978 0.7434672 0.7427859 0.7456224 0.7585987    0
```

```
##
## Kappa
##           Min.   1st Qu.   Median     Mean   3rd Qu.     Max. NA's
## rpart    0.3291271 0.3352490 0.3472442 0.3669742 0.3768489 0.4464020    0
## rf       0.9887176 0.9887204 0.9903344 0.9909754 0.9931474 0.9939574    0
## boosting 0.9448363 0.9484271 0.9492318 0.9497139 0.9499965 0.9560778    0
## lda      0.6038315 0.6224983 0.6227991 0.6236755 0.6242504 0.6449985    0
## nb       0.6564529 0.6603494 0.6712547 0.6718662 0.6800181 0.6912562    0
```

```
dotplot(results)
```



The random forest model seem to have the better results with an average accuracy above 99.2%.

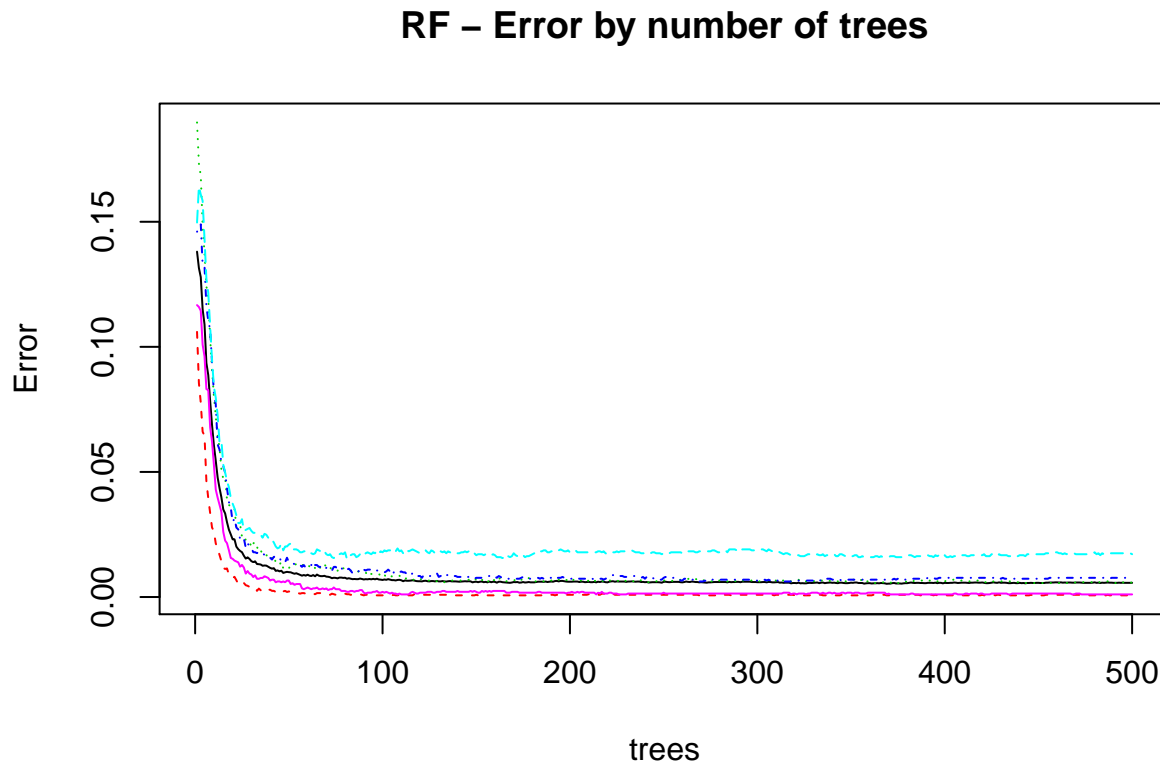
## Check the RF model

```
print(fit.rf)
```

```
## Random Forest
##
## 15699 samples
## 52 predictor
## 5 classes: 'A', 'B', 'C', 'D', 'E'
##
## No pre-processing
## Resampling: Cross-Validated (5 fold)
## Summary of sample sizes: 12561, 12559, 12558, 12560, 12558
## Resampling results across tuning parameters:
##
```

```
## mtry Accuracy Kappa
## 2 0.9928660 0.9909754
## 27 0.9919740 0.9898475
## 52 0.9870059 0.9835611
##
## Accuracy was used to select the optimal model using the largest value.
## The final value used for the model was mtry = 2.
```

```
plot(fit.rf$finalModel,main="RF - Error by number of trees")
```



The best model seems to use the mtry equal to 2. From the graph, the optimum number of tree seem to be 50 or 100. There is no gain with more trees.

## Tune the RF model

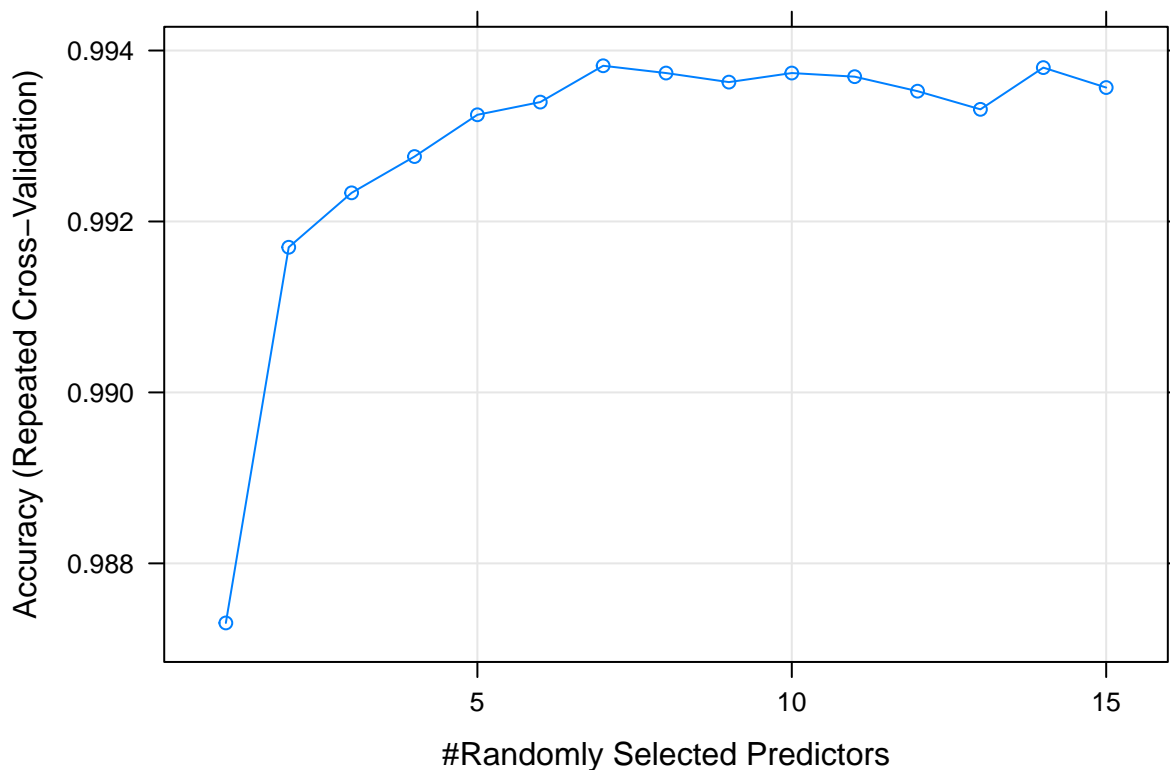
We will try to tune the RF model using a grid search on the mtry parameters. We limit the ntree parameter to 100.

```
set.seed(123)
trControl <- trainControl(method="repeatedcv", number=5, repeats=3, search="grid")
tuneGrid <- expand.grid(.mtry=c(1:15))
fit.gridsearch <- train(classe~., data=training, method="rf",
                        metric=metric, tuneGrid=tuneGrid,
                        trControl=trControl,
                        ntree=100)
print(fit.gridsearch)
```

```
## Random Forest
##
## 15699 samples
```

```
## 52 predictor
## 5 classes: 'A', 'B', 'C', 'D', 'E'
##
## No pre-processing
## Resampling: Cross-Validated (5 fold, repeated 3 times)
## Summary of sample sizes: 12561, 12559, 12558, 12560, 12558, 12558, ...
## Resampling results across tuning parameters:
##
## mtry Accuracy Kappa
## 1 0.9873029 0.9839363
## 2 0.9916981 0.9894972
## 3 0.9923351 0.9903032
## 4 0.9927596 0.9908407
## 5 0.9932481 0.9914588
## 6 0.9933967 0.9916466
## 7 0.9938214 0.9921840
## 8 0.9937364 0.9920765
## 9 0.9936302 0.9919423
## 10 0.9937364 0.9920767
## 11 0.9936939 0.9920226
## 12 0.9935241 0.9918081
## 13 0.9933116 0.9915390
## 14 0.9938001 0.9921570
## 15 0.9935665 0.9918615
##
## Accuracy was used to select the optimal model using the largest value.
## The final value used for the model was mtry = 7.
```

```
plot(fit.gridsearch)
```



The best value for mtry seems to be 7 for an accuracy of 99.4%.

## Validation

We use the validation dataset to predict and compare the results. We will compute the accuracy and the confusion matrix.

```
# predict the result on the validation dataset
predict.rf <- predict(fit.gridsearch,newdata=validation)
conf.rf <- confusionMatrix(validation$classe,predict.rf)
```

We have an accuracy of **99.7%** on the validation dataset.

```
conf.rf$table
```

```
##           Reference
## Prediction   A    B    C    D    E
##           A 1115    1    0    0    0
##           B   2  756    1    0    0
##           C   0   3  681    0    0
##           D   0   0   4  639    0
##           E   0   0   0   1  720
```

## Compute the class for the quiz

```
predict.quiz <- predict(fit.gridsearch,newdata=pmlTesting)
predict.quiz
```

```
## [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
```

## Appendix

Summary:

```
summary(pmlTraining)
```

```
##           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   Min.      : -2.121
```

```

## 1st Qu.: 1.7600 1st Qu.: -88.30 1st Qu.: 3.00 1st Qu.: -1.329
## Median : 5.2800 Median : -13.00 Median :17.00 Median : -0.899
## Mean : 0.3053 Mean : -11.21 Mean :11.31 Mean : -0.220
## 3rd Qu.: 14.9000 3rd Qu.: 12.90 3rd Qu.:18.00 3rd Qu.: -0.219
## Max. : 60.3000 Max. : 179.00 Max. :29.00 Max. :33.000
## NA's :19226
## kurtosis_picth_belt kurtosis_yaw_belt skewness_roll_belt
## Min. : -2.190 Mode:logical Min. : -5.745
## 1st Qu.: -1.107 NA's:19622 1st Qu.: -0.444
## Median : -0.151 Median : 0.000
## Mean : 4.334 Mean : -0.026
## 3rd Qu.: 3.178 3rd Qu.: 0.417
## Max. :58.000 Max. : 3.595
## NA's :19248 NA's :19225
## skewness_roll_belt.1 skewness_yaw_belt max_roll_belt max_picth_belt
## Min. : -7.616 Mode:logical Min. : -94.300 Min. : 3.00
## 1st Qu.: -1.114 NA's:19622 1st Qu.: -88.000 1st Qu.: 5.00
## Median : -0.068 Median : -5.100 Median :18.00
## Mean : -0.296 Mean : -6.667 Mean :12.92
## 3rd Qu.: 0.661 3rd Qu.: 18.500 3rd Qu.:19.00
## Max. : 7.348 Max. :180.000 Max. :30.00
## NA's :19248 NA's :19216 NA's :19216
## max_yaw_belt min_roll_belt min_pitch_belt min_yaw_belt
## Min. : -2.10 Min. : -180.00 Min. : 0.00 Min. : -2.10
## 1st Qu.: -1.30 1st Qu.: -88.40 1st Qu.: 3.00 1st Qu.: -1.30
## Median : -0.90 Median : -7.85 Median :16.00 Median : -0.90
## Mean : -0.22 Mean : -10.44 Mean :10.76 Mean : -0.22
## 3rd Qu.: -0.20 3rd Qu.: 9.05 3rd Qu.:17.00 3rd Qu.: -0.20
## Max. :33.00 Max. : 173.00 Max. :23.00 Max. :33.00
## NA's :19226 NA's :19216 NA's :19216 NA's :19226
## amplitude_roll_belt amplitude_pitch_belt amplitude_yaw_belt
## Min. : 0.000 Min. : 0.000 Min. :0
## 1st Qu.: 0.300 1st Qu.: 1.000 1st Qu.:0
## Median : 1.000 Median : 1.000 Median :0
## Mean : 3.769 Mean : 2.167 Mean :0
## 3rd Qu.: 2.083 3rd Qu.: 2.000 3rd Qu.:0
## Max. :360.000 Max. :12.000 Max. :0
## NA's :19216 NA's :19216 NA's :19226
## 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_pitch_arm kurtosis_yaw_arm skewness_roll_arm
## Min. : -1.809 Min. : -2.084 Min. : -2.103 Min. : -2.541
## 1st Qu.: -1.345 1st Qu.: -1.280 1st Qu.: -1.220 1st Qu.: -0.561
## Median : -0.894 Median : -1.010 Median : -0.733 Median : 0.040
## Mean : -0.366 Mean : -0.542 Mean : 0.406 Mean : 0.068
## 3rd Qu.: -0.038 3rd Qu.: -0.379 3rd Qu.: 0.115 3rd Qu.: 0.671
## Max. : 21.456 Max. : 19.751 Max. : 56.000 Max. : 4.394
## NA's : 19294 NA's : 19296 NA's : 19227 NA's : 19293
## skewness_pitch_arm skewness_yaw_arm max_roll_arm max_pitch_arm
## Min. : -4.565 Min. : -6.708 Min. : -73.100 Min. : -173.000
## 1st Qu.: -0.618 1st Qu.: -0.743 1st Qu.: -0.175 1st Qu.: -1.975
## Median : -0.035 Median : -0.133 Median : 4.950 Median : 23.250
## Mean : -0.065 Mean : -0.229 Mean : 11.236 Mean : 35.751
## 3rd Qu.: 0.454 3rd Qu.: 0.344 3rd Qu.: 26.775 3rd Qu.: 95.975
## Max. : 3.043 Max. : 7.483 Max. : 85.500 Max. : 180.000
## NA's : 19296 NA's : 19227 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_pitch_dumbbell kurtosis_yaw_dumbbell
## Min. : -2.174 Min. : -2.200 Mode: logical
## 1st Qu.: -0.682 1st Qu.: -0.721 NA's: 19622
## Median : -0.033 Median : -0.133
## Mean : 0.452 Mean : 0.286
## 3rd Qu.: 0.940 3rd Qu.: 0.584
## Max. : 54.998 Max. : 55.628
## NA's : 19221 NA's : 19218
## skewness_roll_dumbbell skewness_pitch_dumbbell skewness_yaw_dumbbell
## Min. : -7.384 Min. : -7.447 Mode: logical
## 1st Qu.: -0.581 1st Qu.: -0.526 NA's: 19622

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## Median :-0.076          Median :-0.091
## Mean  :-0.115          Mean   :-0.035
## 3rd Qu.: 0.400          3rd Qu.: 0.505
## Max.   : 1.958          Max.   : 3.769
## NA's   :19220          NA's   :19217
## max_roll_dumbbell max_pitch_dumbbell max_yaw_dumbbell min_roll_dumbbell
## Min.   :-70.10        Min.   :-112.90        Min.   :-2.20        Min.   :-149.60
## 1st Qu.: -27.15        1st Qu.: -66.70        1st Qu.: -0.70        1st Qu.: -59.67
## Median : 14.85         Median : 40.05         Median : 0.00         Median : -43.55
## Mean   : 13.76         Mean   : 32.75         Mean   : 0.45         Mean   : -41.24
## 3rd Qu.: 50.58         3rd Qu.: 133.22        3rd Qu.: 0.90         3rd Qu.: -25.20
## Max.   :137.00         Max.   : 155.00         Max.   :55.00         Max.   : 73.20
## NA's   :19216         NA's   :19216         NA's   :19221         NA's   :19216
## min_pitch_dumbbell min_yaw_dumbbell amplitude_roll_dumbbell
## Min.   :-147.00        Min.   :-2.20        Min.   : 0.00
## 1st Qu.: -91.80        1st Qu.: -0.70        1st Qu.: 14.97
## Median : -66.15        Median : 0.00         Median : 35.05
## Mean   : -33.18        Mean   : 0.45         Mean   : 55.00
## 3rd Qu.: 21.20         3rd Qu.: 0.90         3rd Qu.: 81.04
## Max.   : 120.90        Max.   :55.00         Max.   :256.48
## NA's   :19216         NA's   :19221         NA's   :19216
## amplitude_pitch_dumbbell amplitude_yaw_dumbbell total_accel_dumbbell
## Min.   : 0.00          Min.   :0            Min.   : 0.00
## 1st Qu.: 17.06         1st Qu.:0            1st Qu.: 4.00
## Median : 41.73         Median :0             Median :10.00
## Mean   : 65.93         Mean   :0             Mean   :13.72
## 3rd Qu.: 99.55         3rd Qu.:0            3rd Qu.:19.00
## Max.   :273.59        Max.   :0             Max.   :58.00
## NA's   :19216         NA's   :19221
## 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

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## 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 Min. : -1.879
## 1st Qu.: 0.00 1st Qu.: -68.60 1st Qu.: -1.398
## Median : 9.24 Median : 0.00 Median : -1.119
## Mean : 10.71 Mean : 19.21 Mean : -0.689
## 3rd Qu.: 28.40 3rd Qu.: 110.00 3rd Qu.: -0.618
## Max. : 89.80 Max. : 180.00 Max. : 40.060
##
## NA's :19300
## kurtosis_pitch_forearm kurtosis_yaw_forearm skewness_roll_forearm
## Min. : -2.098 Mode:logical Min. : -2.297
## 1st Qu.: -1.376 NA's:19622 1st Qu.: -0.402
## Median : -0.890 Median : 0.003
## Mean : 0.419 Mean : -0.009
## 3rd Qu.: 0.054 3rd Qu.: 0.370
## Max. : 33.626 Max. : 5.856
## NA's :19301 NA's :19299
## skewness_pitch_forearm skewness_yaw_forearm max_roll_forearm
## Min. : -5.241 Mode:logical Min. : -66.60
## 1st Qu.: -0.881 NA's:19622 1st Qu.: 0.00
## Median : -0.156 Median : 26.80
## Mean : -0.223 Mean : 24.49
## 3rd Qu.: 0.514 3rd Qu.: 45.95
## Max. : 4.464 Max. : 89.80
## NA's :19301 NA's :19216
## max_pitch_forearm max_yaw_forearm min_roll_forearm min_pitch_forearm
## Min. : -151.00 Min. : -1.900 Min. : -72.500 Min. : -180.00
## 1st Qu.: 0.00 1st Qu.: -1.400 1st Qu.: -6.075 1st Qu.: -175.00
## Median : 113.00 Median : -1.100 Median : 0.000 Median : -61.00
## Mean : 81.49 Mean : -0.689 Mean : -0.167 Mean : -57.57
## 3rd Qu.: 174.75 3rd Qu.: -0.600 3rd Qu.: 12.075 3rd Qu.: 0.00
## Max. : 180.00 Max. : 40.100 Max. : 62.100 Max. : 167.00
## NA's :19216 NA's :19300 NA's :19216 NA's :19216
## min_yaw_forearm amplitude_roll_forearm amplitude_pitch_forearm
## Min. : -1.900 Min. : 0.000 Min. : 0.0
## 1st Qu.: -1.400 1st Qu.: 1.125 1st Qu.: 2.0
## Median : -1.100 Median : 17.770 Median : 83.7
## Mean : -0.689 Mean : 24.653 Mean : 139.1
## 3rd Qu.: -0.600 3rd Qu.: 39.875 3rd Qu.: 350.0
## Max. : 40.100 Max. : 126.000 Max. : 360.0
## NA's :19300 NA's :19216 NA's :19216
## amplitude_yaw_forearm total_accel_forearm var_accel_forearm

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## Min. :0 Min. : 0.00 Min. : 0.000
## 1st Qu.:0 1st Qu.: 29.00 1st Qu.: 6.759
## Median :0 Median : 36.00 Median : 21.165
## Mean :0 Mean : 34.72 Mean : 33.502
## 3rd Qu.:0 3rd Qu.: 41.00 3rd Qu.: 51.240
## Max. :0 Max. :108.00 Max. :172.606
## NA's :19300 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
##
##

```