Practical Machine Learning Project

David del Moral

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```
setwd("C:/Users/ddelmoral/Documents/Personal/Learning/Practical Machine Learning/project")

#
train_data <- read.csv("https://d396qusza40orc.cloudfront.net/predmachlearn/pml-training.csv")
test_data  <- read.csv("https://d396qusza40orc.cloudfront.net/predmachlearn/pml-testing.csv")

#
head(train_data)
```

```
##   X user_name raw_timestamp_part_1 raw_timestamp_part_2   cvtd_timestamp
## 1 1  carlitos           1323084231               788290 05/12/2011 11:23
## 2 2  carlitos           1323084231               808298 05/12/2011 11:23
## 3 3  carlitos           1323084231               820366 05/12/2011 11:23
## 4 4  carlitos           1323084232               120339 05/12/2011 11:23
## 5 5  carlitos           1323084232               196328 05/12/2011 11:23
## 6 6  carlitos           1323084232               304277 05/12/2011 11:23
##   new_window num_window roll_belt pitch_belt yaw_belt total_accel_belt
## 1         no         11      1.41       8.07    -94.4                3
## 2         no         11      1.41       8.07    -94.4                3
## 3         no         11      1.42       8.07    -94.4                3
## 4         no         12      1.48       8.05    -94.4                3
## 5         no         12      1.48       8.07    -94.4                3
## 6         no         12      1.45       8.06    -94.4                3
##   kurtosis_roll_belt kurtosis_picth_belt kurtosis_yaw_belt
## 1
## 2
## 3
## 4
## 5
## 6
##   skewness_roll_belt skewness_roll_belt.1 skewness_yaw_belt max_roll_belt
## 1                                                                      NA
## 2                                                                      NA
## 3                                                                      NA
## 4                                                                      NA
## 5                                                                      NA
## 6                                                                      NA
##   max_picth_belt max_yaw_belt min_roll_belt min_pitch_belt min_yaw_belt
## 1             NA                         NA             NA
## 2             NA                         NA             NA
## 3             NA                         NA             NA
## 4             NA                         NA             NA
## 5             NA                         NA             NA
## 6             NA                         NA             NA
##   amplitude_roll_belt amplitude_pitch_belt amplitude_yaw_belt
## 1                  NA                   NA
## 2                  NA                   NA
```

```
## 3                  NA                   NA
## 4                  NA                   NA
## 5                  NA                   NA
## 6                  NA                   NA
##   var_total_accel_belt avg_roll_belt stddev_roll_belt var_roll_belt
## 1                   NA            NA               NA            NA
## 2                   NA            NA               NA            NA
## 3                   NA            NA               NA            NA
## 4                   NA            NA               NA            NA
## 5                   NA            NA               NA            NA
## 6                   NA            NA               NA            NA
##   avg_pitch_belt stddev_pitch_belt var_pitch_belt avg_yaw_belt
## 1             NA                NA             NA           NA
## 2             NA                NA             NA           NA
## 3             NA                NA             NA           NA
## 4             NA                NA             NA           NA
## 5             NA                NA             NA           NA
## 6             NA                NA             NA           NA
##   stddev_yaw_belt var_yaw_belt gyros_belt_x gyros_belt_y gyros_belt_z
## 1              NA           NA         0.00         0.00        -0.02
## 2              NA           NA         0.02         0.00        -0.02
## 3              NA           NA         0.00         0.00        -0.02
## 4              NA           NA         0.02         0.00        -0.03
## 5              NA           NA         0.02         0.02        -0.02
## 6              NA           NA         0.02         0.00        -0.02
##   accel_belt_x accel_belt_y accel_belt_z magnet_belt_x magnet_belt_y
## 1          -21            4           22            -3           599
## 2          -22            4           22            -7           608
## 3          -20            5           23            -2           600
## 4          -22            3           21            -6           604
## 5          -21            2           24            -6           600
## 6          -21            4           21             0           603
##   magnet_belt_z roll_arm pitch_arm yaw_arm total_accel_arm var_accel_arm
## 1          -313     -128      22.5    -161              34            NA
## 2          -311     -128      22.5    -161              34            NA
## 3          -305     -128      22.5    -161              34            NA
## 4          -310     -128      22.1    -161              34            NA
## 5          -302     -128      22.1    -161              34            NA
## 6          -312     -128      22.0    -161              34            NA
##   avg_roll_arm stddev_roll_arm var_roll_arm avg_pitch_arm stddev_pitch_arm
## 1           NA              NA           NA            NA               NA
## 2           NA              NA           NA            NA               NA
## 3           NA              NA           NA            NA               NA
## 4           NA              NA           NA            NA               NA
## 5           NA              NA           NA            NA               NA
## 6           NA              NA           NA            NA               NA
##   var_pitch_arm avg_yaw_arm stddev_yaw_arm var_yaw_arm gyros_arm_x
## 1            NA          NA             NA          NA       0.00
## 2            NA          NA             NA          NA       0.02
## 3            NA          NA             NA          NA       0.02
## 4            NA          NA             NA          NA       0.02
## 5            NA          NA             NA          NA       0.00
## 6            NA          NA             NA          NA       0.02
##   gyros_arm_y gyros_arm_z accel_arm_x accel_arm_y accel_arm_z magnet_arm_x
```

```
## 1        0.00       -0.02        -288         109        -123         -368
## 2       -0.02       -0.02        -290         110        -125         -369
## 3       -0.02       -0.02        -289         110        -126         -368
## 4       -0.03        0.02        -289         111        -123         -372
## 5       -0.03        0.00        -289         111        -123         -374
## 6       -0.03        0.00        -289         111        -122         -369
##   magnet_arm_y magnet_arm_z kurtosis_roll_arm kurtosis_picth_arm
## 1          337          516
## 2          337          513
## 3          344          513
## 4          344          512
## 5          337          506
## 6          342          513
##   kurtosis_yaw_arm skewness_roll_arm skewness_pitch_arm skewness_yaw_arm
## 1
## 2
## 3
## 4
## 5
## 6
##   max_roll_arm max_picth_arm max_yaw_arm min_roll_arm min_pitch_arm
## 1           NA            NA          NA           NA            NA
## 2           NA            NA          NA           NA            NA
## 3           NA            NA          NA           NA            NA
## 4           NA            NA          NA           NA            NA
## 5           NA            NA          NA           NA            NA
## 6           NA            NA          NA           NA            NA
##   min_yaw_arm amplitude_roll_arm amplitude_pitch_arm amplitude_yaw_arm
## 1          NA                 NA                  NA                NA
## 2          NA                 NA                  NA                NA
## 3          NA                 NA                  NA                NA
## 4          NA                 NA                  NA                NA
## 5          NA                 NA                  NA                NA
## 6          NA                 NA                  NA                NA
##   roll_dumbbell pitch_dumbbell yaw_dumbbell kurtosis_roll_dumbbell
## 1      13.05217      -70.49400    -84.87394
## 2      13.13074      -70.63751    -84.71065
## 3      12.85075      -70.27812    -85.14078
## 4      13.43120      -70.39379    -84.87363
## 5      13.37872      -70.42856    -84.85306
## 6      13.38246      -70.81759    -84.46500
##   kurtosis_picth_dumbbell kurtosis_yaw_dumbbell skewness_roll_dumbbell
## 1
## 2
## 3
## 4
## 5
## 6
##   skewness_pitch_dumbbell skewness_yaw_dumbbell max_roll_dumbbell
## 1                                                              NA
## 2                                                              NA
## 3                                                              NA
## 4                                                              NA
## 5                                                              NA
```

```
## 6                                                                 NA
##   max_picth_dumbbell max_yaw_dumbbell min_roll_dumbbell min_pitch_dumbbell
## 1                 NA                                 NA                  NA
## 2                 NA                                 NA                  NA
## 3                 NA                                 NA                  NA
## 4                 NA                                 NA                  NA
## 5                 NA                                 NA                  NA
## 6                 NA                                 NA                  NA
##   min_yaw_dumbbell amplitude_roll_dumbbell amplitude_pitch_dumbbell
## 1                                       NA                       NA
## 2                                       NA                       NA
## 3                                       NA                       NA
## 4                                       NA                       NA
## 5                                       NA                       NA
## 6                                       NA                       NA
##   amplitude_yaw_dumbbell total_accel_dumbbell var_accel_dumbbell
## 1                                         37                NA
## 2                                         37                NA
## 3                                         37                NA
## 4                                         37                NA
## 5                                         37                NA
## 6                                         37                NA
##   avg_roll_dumbbell stddev_roll_dumbbell var_roll_dumbbell
## 1                NA                   NA                NA
## 2                NA                   NA                NA
## 3                NA                   NA                NA
## 4                NA                   NA                NA
## 5                NA                   NA                NA
## 6                NA                   NA                NA
##   avg_pitch_dumbbell stddev_pitch_dumbbell var_pitch_dumbbell
## 1                 NA                    NA                 NA
## 2                 NA                    NA                 NA
## 3                 NA                    NA                 NA
## 4                 NA                    NA                 NA
## 5                 NA                    NA                 NA
## 6                 NA                    NA                 NA
##   avg_yaw_dumbbell stddev_yaw_dumbbell var_yaw_dumbbell gyros_dumbbell_x
## 1               NA                  NA               NA                0
## 2               NA                  NA               NA                0
## 3               NA                  NA               NA                0
## 4               NA                  NA               NA                0
## 5               NA                  NA               NA                0
## 6               NA                  NA               NA                0
##   gyros_dumbbell_y gyros_dumbbell_z accel_dumbbell_x accel_dumbbell_y
## 1            -0.02             0.00             -234               47
## 2            -0.02             0.00             -233               47
## 3            -0.02             0.00             -232               46
## 4            -0.02            -0.02             -232               48
## 5            -0.02             0.00             -233               48
## 6            -0.02             0.00             -234               48
##   accel_dumbbell_z magnet_dumbbell_x magnet_dumbbell_y magnet_dumbbell_z
## 1             -271              -559               293               -65
## 2             -269              -555               296               -64
## 3             -270              -561               298               -63
```

```
## 4             -269             -552              303              -60
## 5             -270             -554              292              -68
## 6             -269             -558              294              -66
##   roll_forearm pitch_forearm yaw_forearm kurtosis_roll_forearm
## 1         28.4         -63.9       -153
## 2         28.3         -63.9       -153
## 3         28.3         -63.9       -152
## 4         28.1         -63.9       -152
## 5         28.0         -63.9       -152
## 6         27.9         -63.9       -152
##   kurtosis_picth_forearm kurtosis_yaw_forearm skewness_roll_forearm
## 1
## 2
## 3
## 4
## 5
## 6
##   skewness_pitch_forearm skewness_yaw_forearm max_roll_forearm
## 1                                                           NA
## 2                                                           NA
## 3                                                           NA
## 4                                                           NA
## 5                                                           NA
## 6                                                           NA
##   max_picth_forearm max_yaw_forearm min_roll_forearm min_pitch_forearm
## 1                NA                              NA                NA
## 2                NA                              NA                NA
## 3                NA                              NA                NA
## 4                NA                              NA                NA
## 5                NA                              NA                NA
## 6                NA                              NA                NA
##   min_yaw_forearm amplitude_roll_forearm amplitude_pitch_forearm
## 1                                     NA                      NA
## 2                                     NA                      NA
## 3                                     NA                      NA
## 4                                     NA                      NA
## 5                                     NA                      NA
## 6                                     NA                      NA
##   amplitude_yaw_forearm total_accel_forearm var_accel_forearm
## 1                                        36                NA
## 2                                        36                NA
## 3                                        36                NA
## 4                                        36                NA
## 5                                        36                NA
## 6                                        36                NA
##   avg_roll_forearm stddev_roll_forearm var_roll_forearm avg_pitch_forearm
## 1               NA                  NA               NA                NA
## 2               NA                  NA               NA                NA
## 3               NA                  NA               NA                NA
## 4               NA                  NA               NA                NA
## 5               NA                  NA               NA                NA
## 6               NA                  NA               NA                NA
##   stddev_pitch_forearm var_pitch_forearm avg_yaw_forearm
## 1                   NA                NA               NA
```

```
## 2                   NA                NA              NA
## 3                   NA                NA              NA
## 4                   NA                NA              NA
## 5                   NA                NA              NA
## 6                   NA                NA              NA
##   stddev_yaw_forearm var_yaw_forearm gyros_forearm_x gyros_forearm_y
## 1                 NA              NA            0.03            0.00
## 2                 NA              NA            0.02            0.00
## 3                 NA              NA            0.03           -0.02
## 4                 NA              NA            0.02           -0.02
## 5                 NA              NA            0.02            0.00
## 6                 NA              NA            0.02           -0.02
##   gyros_forearm_z accel_forearm_x accel_forearm_y accel_forearm_z
## 1           -0.02             192             203            -215
## 2           -0.02             192             203            -216
## 3            0.00             196             204            -213
## 4            0.00             189             206            -214
## 5           -0.02             189             206            -214
## 6           -0.03             193             203            -215
##   magnet_forearm_x magnet_forearm_y magnet_forearm_z classe
## 1              -17              654              476      A
## 2              -18              661              473      A
## 3              -18              658              469      A
## 4              -16              658              469      A
## 5              -17              655              473      A
## 6               -9              660              478      A
```

```
#
head(test_data)
```

```
##   X user_name raw_timestamp_part_1 raw_timestamp_part_2   cvtd_timestamp
## 1 1     pedro           1323095002               868349 05/12/2011 14:23
## 2 2    jeremy           1322673067               778725 30/11/2011 17:11
## 3 3    jeremy           1322673075               342967 30/11/2011 17:11
## 4 4    adelmo           1322832789               560311 02/12/2011 13:33
## 5 5    eurico           1322489635               814776 28/11/2011 14:13
## 6 6    jeremy           1322673149               510661 30/11/2011 17:12
##   new_window num_window roll_belt pitch_belt yaw_belt total_accel_belt
## 1         no         74    123.00      27.00    -4.75               20
## 2         no        431      1.02       4.87   -88.90                4
## 3         no        439      0.87       1.82   -88.50                5
## 4         no        194    125.00     -41.60   162.00               17
## 5         no        235      1.35       3.33   -88.60                3
## 6         no        504     -5.92       1.59   -87.70                4
##   kurtosis_roll_belt kurtosis_picth_belt kurtosis_yaw_belt
## 1                 NA                  NA                NA
## 2                 NA                  NA                NA
## 3                 NA                  NA                NA
## 4                 NA                  NA                NA
## 5                 NA                  NA                NA
## 6                 NA                  NA                NA
##   skewness_roll_belt skewness_roll_belt.1 skewness_yaw_belt max_roll_belt
## 1                 NA                   NA                NA            NA
## 2                 NA                   NA                NA            NA
## 3                 NA                   NA                NA            NA
```

```
## 4                NA                   NA                NA            NA
## 5                NA                   NA                NA            NA
## 6                NA                   NA                NA            NA
##   max_picth_belt max_yaw_belt min_roll_belt min_pitch_belt min_yaw_belt
## 1             NA           NA            NA             NA           NA
## 2             NA           NA            NA             NA           NA
## 3             NA           NA            NA             NA           NA
## 4             NA           NA            NA             NA           NA
## 5             NA           NA            NA             NA           NA
## 6             NA           NA            NA             NA           NA
##   amplitude_roll_belt amplitude_pitch_belt amplitude_yaw_belt
## 1                  NA                   NA                 NA
## 2                  NA                   NA                 NA
## 3                  NA                   NA                 NA
## 4                  NA                   NA                 NA
## 5                  NA                   NA                 NA
## 6                  NA                   NA                 NA
##   var_total_accel_belt avg_roll_belt stddev_roll_belt var_roll_belt
## 1                   NA            NA                NA            NA
## 2                   NA            NA                NA            NA
## 3                   NA            NA                NA            NA
## 4                   NA            NA                NA            NA
## 5                   NA            NA                NA            NA
## 6                   NA            NA                NA            NA
##   avg_pitch_belt stddev_pitch_belt var_pitch_belt avg_yaw_belt
## 1             NA                NA             NA           NA
## 2             NA                NA             NA           NA
## 3             NA                NA             NA           NA
## 4             NA                NA             NA           NA
## 5             NA                NA             NA           NA
## 6             NA                NA             NA           NA
##   stddev_yaw_belt var_yaw_belt gyros_belt_x gyros_belt_y gyros_belt_z
## 1              NA           NA        -0.50        -0.02        -0.46
## 2              NA           NA        -0.06        -0.02        -0.07
## 3              NA           NA         0.05         0.02         0.03
## 4              NA           NA         0.11         0.11        -0.16
## 5              NA           NA         0.03         0.02         0.00
## 6              NA           NA         0.10         0.05        -0.13
##   accel_belt_x accel_belt_y accel_belt_z magnet_belt_x magnet_belt_y
## 1          -38           69         -179           -13           581
## 2          -13           11           39            43           636
## 3            1           -1           49            29           631
## 4           46           45         -156           169           608
## 5           -8            4           27            33           566
## 6          -11          -16           38            31           638
##   magnet_belt_z roll_arm pitch_arm yaw_arm total_accel_arm var_accel_arm
## 1          -382     40.7    -27.80     178              10            NA
## 2          -309      0.0      0.00       0              38            NA
## 3          -312      0.0      0.00       0              44            NA
## 4          -304   -109.0     55.00    -142              25            NA
## 5          -418     76.1      2.76     102              29            NA
## 6          -291      0.0      0.00       0              14            NA
##   avg_roll_arm stddev_roll_arm var_roll_arm avg_pitch_arm stddev_pitch_arm
## 1           NA              NA           NA            NA               NA
```

```
## 2           NA              NA           NA            NA               NA
## 3           NA              NA           NA            NA               NA
## 4           NA              NA           NA            NA               NA
## 5           NA              NA           NA            NA               NA
## 6           NA              NA           NA            NA               NA
##   var_pitch_arm avg_yaw_arm stddev_yaw_arm var_yaw_arm gyros_arm_x
## 1            NA          NA             NA          NA       -1.65
## 2            NA          NA             NA          NA       -1.17
## 3            NA          NA             NA          NA        2.10
## 4            NA          NA             NA          NA        0.22
## 5            NA          NA             NA          NA       -1.96
## 6            NA          NA             NA          NA        0.02
##   gyros_arm_y gyros_arm_z accel_arm_x accel_arm_y accel_arm_z magnet_arm_x
## 1        0.48       -0.18          16          38          93         -326
## 2        0.85       -0.43        -290         215         -90         -325
## 3       -1.36        1.13        -341         245         -87         -264
## 4       -0.51        0.92        -238         -57           6         -173
## 5        0.79       -0.54        -197         200         -30         -170
## 6        0.05       -0.07         -26         130         -19          396
##   magnet_arm_y magnet_arm_z kurtosis_roll_arm kurtosis_picth_arm
## 1          385          481                NA                 NA
## 2          447          434                NA                 NA
## 3          474          413                NA                 NA
## 4          257          633                NA                 NA
## 5          275          617                NA                 NA
## 6          176          516                NA                 NA
##   kurtosis_yaw_arm skewness_roll_arm skewness_pitch_arm skewness_yaw_arm
## 1               NA                NA                 NA               NA
## 2               NA                NA                 NA               NA
## 3               NA                NA                 NA               NA
## 4               NA                NA                 NA               NA
## 5               NA                NA                 NA               NA
## 6               NA                NA                 NA               NA
##   max_roll_arm max_picth_arm max_yaw_arm min_roll_arm min_pitch_arm
## 1           NA            NA          NA           NA            NA
## 2           NA            NA          NA           NA            NA
## 3           NA            NA          NA           NA            NA
## 4           NA            NA          NA           NA            NA
## 5           NA            NA          NA           NA            NA
## 6           NA            NA          NA           NA            NA
##   min_yaw_arm amplitude_roll_arm amplitude_pitch_arm amplitude_yaw_arm
## 1          NA                NA                 NA               NA
## 2          NA                NA                 NA               NA
## 3          NA                NA                 NA               NA
## 4          NA                NA                 NA               NA
## 5          NA                NA                 NA               NA
## 6          NA                NA                 NA               NA
##   roll_dumbbell pitch_dumbbell yaw_dumbbell kurtosis_roll_dumbbell
## 1     -17.73748       24.96085    126.23596                     NA
## 2      54.47761      -53.69758    -75.51480                     NA
## 3      57.07031      -51.37303    -75.20287                     NA
## 4      43.10927      -30.04885   -103.32003                     NA
## 5    -101.38396      -53.43952    -14.19542                     NA
## 6      62.18750      -50.55595    -71.12063                     NA
```

```
##   kurtosis_picth_dumbbell kurtosis_yaw_dumbbell skewness_roll_dumbbell
## 1                      NA                    NA                     NA
## 2                      NA                    NA                     NA
## 3                      NA                    NA                     NA
## 4                      NA                    NA                     NA
## 5                      NA                    NA                     NA
## 6                      NA                    NA                     NA
##   skewness_pitch_dumbbell skewness_yaw_dumbbell max_roll_dumbbell
## 1                      NA                    NA                NA
## 2                      NA                    NA                NA
## 3                      NA                    NA                NA
## 4                      NA                    NA                NA
## 5                      NA                    NA                NA
## 6                      NA                    NA                NA
##   max_picth_dumbbell max_yaw_dumbbell min_roll_dumbbell min_pitch_dumbbell
## 1                 NA                NA                NA                 NA
## 2                 NA                NA                NA                 NA
## 3                 NA                NA                NA                 NA
## 4                 NA                NA                NA                 NA
## 5                 NA                NA                NA                 NA
## 6                 NA                NA                NA                 NA
##   min_yaw_dumbbell amplitude_roll_dumbbell amplitude_pitch_dumbbell
## 1               NA                      NA                       NA
## 2               NA                      NA                       NA
## 3               NA                      NA                       NA
## 4               NA                      NA                       NA
## 5               NA                      NA                       NA
## 6               NA                      NA                       NA
##   amplitude_yaw_dumbbell total_accel_dumbbell var_accel_dumbbell
## 1                     NA                    9                NA
## 2                     NA                   31                NA
## 3                     NA                   29                NA
## 4                     NA                   18                NA
## 5                     NA                    4                NA
## 6                     NA                   29                NA
##   avg_roll_dumbbell stddev_roll_dumbbell var_roll_dumbbell
## 1                NA                   NA                NA
## 2                NA                   NA                NA
## 3                NA                   NA                NA
## 4                NA                   NA                NA
## 5                NA                   NA                NA
## 6                NA                   NA                NA
##   avg_pitch_dumbbell stddev_pitch_dumbbell var_pitch_dumbbell
## 1                 NA                    NA                 NA
## 2                 NA                    NA                 NA
## 3                 NA                    NA                 NA
## 4                 NA                    NA                 NA
## 5                 NA                    NA                 NA
## 6                 NA                    NA                 NA
##   avg_yaw_dumbbell stddev_yaw_dumbbell var_yaw_dumbbell gyros_dumbbell_x
## 1               NA                   NA               NA             0.64
## 2               NA                   NA               NA             0.34
## 3               NA                   NA               NA             0.39
## 4               NA                   NA               NA             0.10
```

```
## 5               NA                  NA               NA             0.29
## 6               NA                  NA               NA            -0.59
##   gyros_dumbbell_y gyros_dumbbell_z accel_dumbbell_x accel_dumbbell_y
## 1             0.06            -0.61               21              -15
## 2             0.05            -0.71             -153              155
## 3             0.14            -0.34             -141              155
## 4            -0.02             0.05              -51               72
## 5            -0.47            -0.46              -18              -30
## 6             0.80             1.10             -138              166
##   accel_dumbbell_z magnet_dumbbell_x magnet_dumbbell_y magnet_dumbbell_z
## 1               81               523              -528               -56
## 2             -205              -502               388               -36
## 3             -196              -506               349                41
## 4             -148              -576               238                53
## 5               -5              -424               252               312
## 6             -186              -543               262                96
##   roll_forearm pitch_forearm yaw_forearm kurtosis_roll_forearm
## 1          141         49.30       156.0                    NA
## 2          109        -17.60       106.0                    NA
## 3          131        -32.60        93.0                    NA
## 4            0          0.00         0.0                    NA
## 5         -176         -2.16       -47.9                    NA
## 6          150          1.46        89.7                    NA
##   kurtosis_picth_forearm kurtosis_yaw_forearm skewness_roll_forearm
## 1                     NA                   NA                    NA
## 2                     NA                   NA                    NA
## 3                     NA                   NA                    NA
## 4                     NA                   NA                    NA
## 5                     NA                   NA                    NA
## 6                     NA                   NA                    NA
##   skewness_pitch_forearm skewness_yaw_forearm max_roll_forearm
## 1                     NA                   NA               NA
## 2                     NA                   NA               NA
## 3                     NA                   NA               NA
## 4                     NA                   NA               NA
## 5                     NA                   NA               NA
## 6                     NA                   NA               NA
##   max_picth_forearm max_yaw_forearm min_roll_forearm min_pitch_forearm
## 1                NA              NA               NA                NA
## 2                NA              NA               NA                NA
## 3                NA              NA               NA                NA
## 4                NA              NA               NA                NA
## 5                NA              NA               NA                NA
## 6                NA              NA               NA                NA
##   min_yaw_forearm amplitude_roll_forearm amplitude_pitch_forearm
## 1              NA                     NA                      NA
## 2              NA                     NA                      NA
## 3              NA                     NA                      NA
## 4              NA                     NA                      NA
## 5              NA                     NA                      NA
## 6              NA                     NA                      NA
##   amplitude_yaw_forearm total_accel_forearm var_accel_forearm
## 1                    NA                 33               NA
## 2                    NA                 39               NA
```

```
## 3                    NA                 34               NA
## 4                    NA                 43               NA
## 5                    NA                 24               NA
## 6                    NA                 43               NA
##   avg_roll_forearm stddev_roll_forearm var_roll_forearm avg_pitch_forearm
## 1               NA                  NA               NA                NA
## 2               NA                  NA               NA                NA
## 3               NA                  NA               NA                NA
## 4               NA                  NA               NA                NA
## 5               NA                  NA               NA                NA
## 6               NA                  NA               NA                NA
##   stddev_pitch_forearm var_pitch_forearm avg_yaw_forearm
## 1                   NA                NA              NA
## 2                   NA                NA              NA
## 3                   NA                NA              NA
## 4                   NA                NA              NA
## 5                   NA                NA              NA
## 6                   NA                NA              NA
##   stddev_yaw_forearm var_yaw_forearm gyros_forearm_x gyros_forearm_y
## 1                 NA              NA            0.74           -3.34
## 2                 NA              NA            1.12           -2.78
## 3                 NA              NA            0.18           -0.79
## 4                 NA              NA            1.38            0.69
## 5                 NA              NA           -0.75            3.10
## 6                 NA              NA           -0.88            4.26
##   gyros_forearm_z accel_forearm_x accel_forearm_y accel_forearm_z
## 1           -0.59            -110             267            -149
## 2           -0.18             212             297            -118
## 3            0.28             154             271            -129
## 4            1.80             -92             406             -39
## 5            0.80             131             -93             172
## 6            1.35             230             322            -144
##   magnet_forearm_x magnet_forearm_y magnet_forearm_z problem_id
## 1             -714              419              617          1
## 2             -237              791              873          2
## 3              -51              698              783          3
## 4             -233              783              521          4
## 5              375             -787               91          5
## 6             -300              800              884          6
```

```
summary(train_data)
```

```
##        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_picth_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
##
##
```

```
ncol(train_data)
```

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

```
nrow(train_data)
```

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

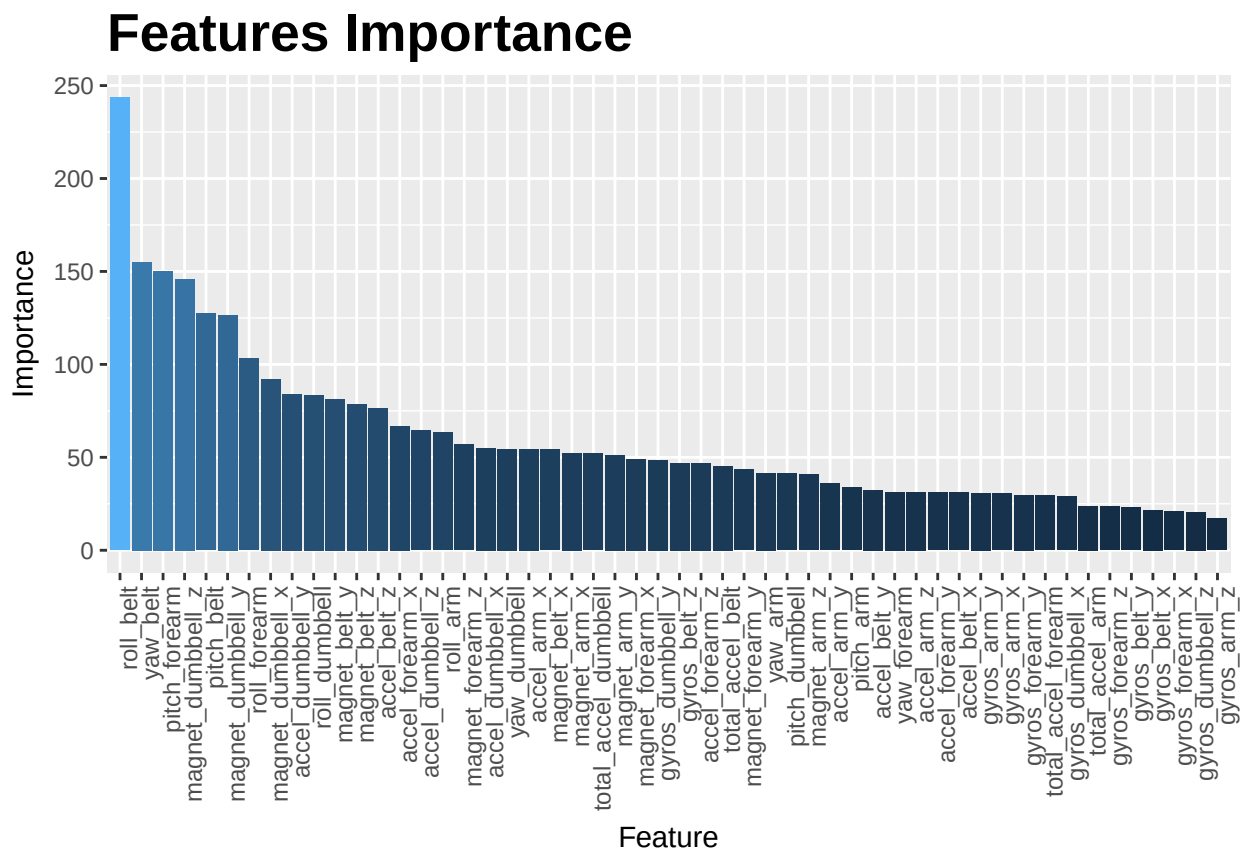
We can observe that the data set contains 160 variables and 19622 records. We need to perform data cleansing before processing.

Data cleansing

Removing first 7 columns, which only include log info seq No, user_name,time_stamp etc. these are no relevant for the prediction.

```
clean_data<-train_data[, -(1:7)]

### Removing colums containing NA or ""

thres <- nrow(clean_data) * 0.95

nNaColumns <- !apply(clean_data, 2, function(x) sum(is.na(x)) > thres  || sum(x=="") > thres)
```

```
clean_data <- clean_data[, nNaColumns]


### Removing near zero variance columns

nzColumns <- nearZeroVar(clean_data, saveMetrics = TRUE)

clean_data <- clean_data[, nzColumns$nzv==FALSE]

clean_data$classe = factor(clean_data$classe)


###Determining variable importances analysis

set.seed(20020223)

##  20% data for importance analysis

inAnalysis    <- createDataPartition(clean_data$classe, p = 0.2, list = FALSE)

analysis.set  <- clean_data[inAnalysis, ]

model_analysis<-randomForest(classe ~.,data=analysis.set)

imp_Vars <- varImp(model_analysis)

varnames<-rownames(imp_Vars)

var_Order<-data.frame(varnames=varnames,imp_Vars)

var_Order<-arrange(var_Order, desc(Overall))

# Plotting relevant variables
 ggplot(var_Order, aes(x=reorder(varnames, desc(Overall)), y=Overall, fill=Overall)) +
    geom_bar(stat="identity") +
    theme(legend.position="none") +
    guides(fill=FALSE) +
    xlab("Feature") +
    ylab("Importance") +
    ggtitle("Features Importance") +
    theme(axis.text.x = element_text(angle=90, hjust=1)) +
    theme(plot.title  = element_text(size=20,  face="bold"))
```



Determining relevant variables

Trimming non important variables form the data set whose importance value is less than 30

```
var_Order[1:40,]
```

```
##                varnames   Overall
## 1             roll_belt 243.48273
## 2              yaw_belt 155.04218
## 3         pitch_forearm 150.38118
## 4     magnet_dumbbell_z 145.87449
## 5            pitch_belt 127.34531
## 6     magnet_dumbbell_y 126.57017
## 7          roll_forearm 103.07586
## 8     magnet_dumbbell_x  92.25215
## 9      accel_dumbbell_y  84.07665
## 10        roll_dumbbell  83.51051
## 11        magnet_belt_y  81.47988
## 12        magnet_belt_z  78.64576
## 13         accel_belt_z  76.63276
## 14      accel_forearm_x  66.77200
## 15     accel_dumbbell_z  64.39351
## 16             roll_arm  63.26340
## 17     magnet_forearm_z  56.84799
## 18     accel_dumbbell_x  55.11514
## 19         yaw_dumbbell  54.52048
```

```
## 20          accel_arm_x  54.38052
## 21        magnet_belt_x  54.31884
## 22         magnet_arm_x  52.31029
## 23 total_accel_dumbbell  51.94664
## 24         magnet_arm_y  51.18655
## 25     magnet_forearm_x  49.02068
## 26     gyros_dumbbell_y  48.62970
## 27         gyros_belt_z  47.00208
## 28      accel_forearm_z  46.90614
## 29     total_accel_belt  45.24127
## 30     magnet_forearm_y  43.35898
## 31              yaw_arm  41.71260
## 32       pitch_dumbbell  41.28831
## 33         magnet_arm_z  40.86580
## 34          accel_arm_y  35.90416
## 35            pitch_arm  33.66558
## 36         accel_belt_y  32.43241
## 37          yaw_forearm  31.40696
## 38          accel_arm_z  31.29909
## 39      accel_forearm_y  31.17596
## 40         accel_belt_x  31.01823
```

```
Rel_Names<-as.character(var_Order[var_Order$Overall>30,]$varnames)

Rel_Names<-c("classe",Rel_Names)

Most_Rel_Cols<-unlist(lapply(names(clean_data), function(name){name %in% Rel_Names}))

clean_data<-clean_data[,Most_Rel_Cols]

ncol(clean_data)
```

```
## [1] 43
```

After selecting relevant variables only 39 were left.

Data Partitioning

```
###Data partition

inTrain <- createDataPartition(clean_data$classe, p = 0.75, list = FALSE)

train_set <- clean_data[inTrain, ]  ##  75% data as the train data

test_set <- clean_data[ -inTrain, ]
```

Prediction models training

Prediction models are Random Forest and KNN methods.

In the following code with the trained models, cross-validation on the testing data set is performed:

```
modRF<-randomForest(classe ~.,data=train_set)
```

```r
ctrlKNN = trainControl(method = "adaptive_cv")

modKNN = train(classe ~ ., data=train_set, method = "knn", trControl = ctrlKNN)

predRF<-predict(modRF,test_set)

rfMatrix<-confusionMatrix(predRF, test_set$classe)

rfMatrix
```

```
## Confusion Matrix and Statistics
##
##           Reference
## Prediction    A    B    C    D    E
##          A 1394    1    0    0    0
##          B    1  945    3    0    0
##          C    0    3  852    6    1
##          D    0    0    0  798    0
##          E    0    0    0    0  900
##
## Overall Statistics
##
##                Accuracy : 0.9969
##                  95% CI : (0.995, 0.9983)
##     No Information Rate : 0.2845
##     P-Value [Acc > NIR] : < 2.2e-16
##
##                   Kappa : 0.9961
##  Mcnemar's Test P-Value : NA
##
## Statistics by Class:
##
##                      Class: A Class: B Class: C Class: D Class: E
## Sensitivity            0.9993   0.9958   0.9965   0.9925   0.9989
## Specificity            0.9997   0.9990   0.9975   1.0000   1.0000
## Pos Pred Value         0.9993   0.9958   0.9884   1.0000   1.0000
## Neg Pred Value         0.9997   0.9990   0.9993   0.9985   0.9998
## Prevalence             0.2845   0.1935   0.1743   0.1639   0.1837
## Detection Rate         0.2843   0.1927   0.1737   0.1627   0.1835
## Detection Prevalence   0.2845   0.1935   0.1758   0.1627   0.1835
## Balanced Accuracy      0.9995   0.9974   0.9970   0.9963   0.9994
```

Confusion Matrix and Statistics

Submitting cases

Predicting results are sown below:

```r
answer <- predict(modRF, test_data)

answer
```

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

Conclusions

- For this project a predicting model manner of people doing exercise was made. NAs and blank columns were remove as well non-changed columnes and log columns non relevant for predictions. Variables were reduced from 160 to 39.
- Despite the reduction the Random Forest still has an 0.9957 accuracy rate.
- The resulting KNN's (k-nearest neighbors) accuracy is 0.918.
- The Random Forest method's out of sample error rate is: 0.0043.
- The KNN method's out of sample error rate is: 0.082.
- Because the Random Forest method has the lower out of sample error rate, it was selected to predict the required 20 test cases.
- It can be observed that submitting results to the grader, it is obtained a 100% correctness.