PML_Week4_Project

Background

This project focus on analysis of how well (the quality) that participant perform in a lift exercises. The sensors are on belt, forarm, arm and dumbel. Six young health participants were asked to perform one set of 10 repetitions of the Unilateral Dumbbell Biceps Curl in five different fashions: exactly according to the specification (Class A), throwing the elbows to the front (Class B), lifting the dumbbell only halfway (Class C), lowering the dumbbell only halfway (Class D) and throwing the hips to the front (Class E). Read more: http://groupware.les.inf.puc-rio.br/har#ixzz5a9QMb32m (http://groupware.les.inf.puc-rio.br/har#ixzz5a9QMb32m)

Exploratory Data

load library and data

```
setwd("~/R_MW_20180914/PMLWeek4")
library(caret)
```

```
## Loading required package: lattice
```

```
## Loading required package: ggplot2
```

```
library(corrplot)
```

```
## corrplot 0.84 loaded
```

```
library(Hmisc)
```

```
## Loading required package: survival
```

```
##
## Attaching package: 'survival'
```

```
## The following object is masked from 'package:caret':
##
##     cluster
```

```
## Loading required package: Formula
```

```
##
## Attaching package: 'Hmisc'
```

```
## The following objects are masked from 'package:base':
##
##     format.pval, units
```

```
data.train <- read.csv("pml-training.csv")
data.test <- read.csv("pml-testing.csv")

dim(data.train)
```

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

```
dim(data.test)
```

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

```
head(data.train)
```

```
##   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
```

```
names(data.train)
```

```
##    [1] "X"                          "user_name"
##    [3] "raw_timestamp_part_1"       "raw_timestamp_part_2"
##    [5] "cvtd_timestamp"             "new_window"
##    [7] "num_window"                 "roll_belt"
##    [9] "pitch_belt"                 "yaw_belt"
##   [11] "total_accel_belt"           "kurtosis_roll_belt"
##   [13] "kurtosis_picth_belt"        "kurtosis_yaw_belt"
##   [15] "skewness_roll_belt"         "skewness_roll_belt.1"
##   [17] "skewness_yaw_belt"          "max_roll_belt"
##   [19] "max_picth_belt"             "max_yaw_belt"
##   [21] "min_roll_belt"              "min_pitch_belt"
##   [23] "min_yaw_belt"               "amplitude_roll_belt"
##   [25] "amplitude_pitch_belt"       "amplitude_yaw_belt"
##   [27] "var_total_accel_belt"       "avg_roll_belt"
##   [29] "stddev_roll_belt"           "var_roll_belt"
##   [31] "avg_pitch_belt"             "stddev_pitch_belt"
##   [33] "var_pitch_belt"             "avg_yaw_belt"
##   [35] "stddev_yaw_belt"            "var_yaw_belt"
##   [37] "gyros_belt_x"               "gyros_belt_y"
##   [39] "gyros_belt_z"               "accel_belt_x"
##   [41] "accel_belt_y"               "accel_belt_z"
##   [43] "magnet_belt_x"              "magnet_belt_y"
##   [45] "magnet_belt_z"              "roll_arm"
##   [47] "pitch_arm"                  "yaw_arm"
##   [49] "total_accel_arm"            "var_accel_arm"
##   [51] "avg_roll_arm"               "stddev_roll_arm"
##   [53] "var_roll_arm"               "avg_pitch_arm"
##   [55] "stddev_pitch_arm"           "var_pitch_arm"
##   [57] "avg_yaw_arm"                "stddev_yaw_arm"
##   [59] "var_yaw_arm"                "gyros_arm_x"
##   [61] "gyros_arm_y"                "gyros_arm_z"
##   [63] "accel_arm_x"                "accel_arm_y"
##   [65] "accel_arm_z"                "magnet_arm_x"
##   [67] "magnet_arm_y"               "magnet_arm_z"
##   [69] "kurtosis_roll_arm"          "kurtosis_picth_arm"
##   [71] "kurtosis_yaw_arm"           "skewness_roll_arm"
##   [73] "skewness_pitch_arm"         "skewness_yaw_arm"
##   [75] "max_roll_arm"               "max_picth_arm"
##   [77] "max_yaw_arm"                "min_roll_arm"
##   [79] "min_pitch_arm"              "min_yaw_arm"
##   [81] "amplitude_roll_arm"         "amplitude_pitch_arm"
##   [83] "amplitude_yaw_arm"          "roll_dumbbell"
##   [85] "pitch_dumbbell"             "yaw_dumbbell"
##   [87] "kurtosis_roll_dumbbell"     "kurtosis_picth_dumbbell"
##   [89] "kurtosis_yaw_dumbbell"      "skewness_roll_dumbbell"
##   [91] "skewness_pitch_dumbbell"    "skewness_yaw_dumbbell"
##   [93] "max_roll_dumbbell"          "max_picth_dumbbell"
##   [95] "max_yaw_dumbbell"           "min_roll_dumbbell"
```

```
##   [97] "min_pitch_dumbbell"        "min_yaw_dumbbell"
##   [99] "amplitude_roll_dumbbell"   "amplitude_pitch_dumbbell"
##  [101] "amplitude_yaw_dumbbell"    "total_accel_dumbbell"
##  [103] "var_accel_dumbbell"        "avg_roll_dumbbell"
##  [105] "stddev_roll_dumbbell"      "var_roll_dumbbell"
##  [107] "avg_pitch_dumbbell"        "stddev_pitch_dumbbell"
##  [109] "var_pitch_dumbbell"        "avg_yaw_dumbbell"
##  [111] "stddev_yaw_dumbbell"       "var_yaw_dumbbell"
##  [113] "gyros_dumbbell_x"          "gyros_dumbbell_y"
##  [115] "gyros_dumbbell_z"          "accel_dumbbell_x"
##  [117] "accel_dumbbell_y"          "accel_dumbbell_z"
##  [119] "magnet_dumbbell_x"         "magnet_dumbbell_y"
##  [121] "magnet_dumbbell_z"         "roll_forearm"
##  [123] "pitch_forearm"             "yaw_forearm"
##  [125] "kurtosis_roll_forearm"     "kurtosis_picth_forearm"
##  [127] "kurtosis_yaw_forearm"      "skewness_roll_forearm"
##  [129] "skewness_pitch_forearm"    "skewness_yaw_forearm"
##  [131] "max_roll_forearm"          "max_picth_forearm"
##  [133] "max_yaw_forearm"           "min_roll_forearm"
##  [135] "min_pitch_forearm"         "min_yaw_forearm"
##  [137] "amplitude_roll_forearm"    "amplitude_pitch_forearm"
##  [139] "amplitude_yaw_forearm"     "total_accel_forearm"
##  [141] "var_accel_forearm"         "avg_roll_forearm"
##  [143] "stddev_roll_forearm"       "var_roll_forearm"
##  [145] "avg_pitch_forearm"         "stddev_pitch_forearm"
##  [147] "var_pitch_forearm"         "avg_yaw_forearm"
##  [149] "stddev_yaw_forearm"        "var_yaw_forearm"
##  [151] "gyros_forearm_x"           "gyros_forearm_y"
##  [153] "gyros_forearm_z"           "accel_forearm_x"
##  [155] "accel_forearm_y"           "accel_forearm_z"
##  [157] "magnet_forearm_x"          "magnet_forearm_y"
##  [159] "magnet_forearm_z"          "classe"
```

clean the data

remove variable that over 90% is NA

```
Nval <- sapply(data.train, function(x) mean(is.na(x))) > 0.90

clean.train <-data.train[,Nval == FALSE]
clean.test <-data.test[,Nval== FALSE]

dim(clean.train)
```

```
## [1] 19622    93
```

```
dim(clean.test)
```

```
## [1] 20 93
```

remove columns that are not relevant to accelerometer measurements

```
trainRemove<- grepl("^X|timestamp|window", names(clean.train))
clean.train<- clean.train[, !trainRemove]
clean.train<- clean.train[, sapply(clean.train, is.numeric)]

classe<- data.train$classe
clean.train$classe <- classe

testRemove<- grepl("^X|timestamp|window", names(clean.test))
clean.test<- clean.test[, !testRemove]
clean.test<- clean.test[, sapply(clean.test, is.numeric)]


head(clean.train)
```

```
##   roll_belt pitch_belt yaw_belt total_accel_belt gyros_belt_x gyros_belt_y
## 1      1.41       8.07    -94.4                3         0.00         0.00
## 2      1.41       8.07    -94.4                3         0.02         0.00
## 3      1.42       8.07    -94.4                3         0.00         0.00
## 4      1.48       8.05    -94.4                3         0.02         0.00
## 5      1.48       8.07    -94.4                3         0.02         0.02
## 6      1.45       8.06    -94.4                3         0.02         0.00
##   gyros_belt_z accel_belt_x accel_belt_y accel_belt_z magnet_belt_x
## 1        -0.02          -21            4           22            -3
## 2        -0.02          -22            4           22            -7
## 3        -0.02          -20            5           23            -2
## 4        -0.03          -22            3           21            -6
## 5        -0.02          -21            2           24            -6
## 6        -0.02          -21            4           21             0
##   magnet_belt_y magnet_belt_z roll_arm pitch_arm yaw_arm total_accel_arm
## 1           599          -313     -128      22.5    -161              34
## 2           608          -311     -128      22.5    -161              34
## 3           600          -305     -128      22.5    -161              34
## 4           604          -310     -128      22.1    -161              34
## 5           600          -302     -128      22.1    -161              34
## 6           603          -312     -128      22.0    -161              34
##   gyros_arm_x gyros_arm_y gyros_arm_z accel_arm_x accel_arm_y accel_arm_z
## 1        0.00        0.00       -0.02        -288         109        -123
## 2        0.02       -0.02       -0.02        -290         110        -125
## 3        0.02       -0.02       -0.02        -289         110        -126
## 4        0.02       -0.03        0.02        -289         111        -123
## 5        0.00       -0.03        0.00        -289         111        -123
## 6        0.02       -0.03        0.00        -289         111        -122
##   magnet_arm_x magnet_arm_y magnet_arm_z roll_dumbbell pitch_dumbbell
## 1         -368          337          516      13.05217      -70.49400
## 2         -369          337          513      13.13074      -70.63751
## 3         -368          344          513      12.85075      -70.27812
## 4         -372          344          512      13.43120      -70.39379
## 5         -374          337          506      13.37872      -70.42856
## 6         -369          342          513      13.38246      -70.81759
##   yaw_dumbbell total_accel_dumbbell gyros_dumbbell_x gyros_dumbbell_y
## 1    -84.87394                   37                0            -0.02
## 2    -84.71065                   37                0            -0.02
## 3    -85.14078                   37                0            -0.02
## 4    -84.87363                   37                0            -0.02
## 5    -84.85306                   37                0            -0.02
## 6    -84.46500                   37                0            -0.02
##   gyros_dumbbell_z accel_dumbbell_x accel_dumbbell_y accel_dumbbell_z
## 1             0.00             -234               47             -271
## 2             0.00             -233               47             -269
## 3             0.00             -232               46             -270
## 4            -0.02             -232               48             -269
## 5             0.00             -233               48             -270
```

```
## 6                0.00              -234                48              -269
##    magnet_dumbbell_x magnet_dumbbell_y magnet_dumbbell_z roll_forearm
## 1              -559               293               -65         28.4
## 2              -555               296               -64         28.3
## 3              -561               298               -63         28.3
## 4              -552               303               -60         28.1
## 5              -554               292               -68         28.0
## 6              -558               294               -66         27.9
##    pitch_forearm yaw_forearm total_accel_forearm gyros_forearm_x
## 1         -63.9        -153                  36            0.03
## 2         -63.9        -153                  36            0.02
## 3         -63.9        -152                  36            0.03
## 4         -63.9        -152                  36            0.02
## 5         -63.9        -152                  36            0.02
## 6         -63.9        -152                  36            0.02
##    gyros_forearm_y gyros_forearm_z accel_forearm_x accel_forearm_y
## 1            0.00           -0.02             192             203
## 2            0.00           -0.02             192             203
## 3           -0.02            0.00             196             204
## 4           -0.02            0.00             189             206
## 5            0.00           -0.02             189             206
## 6           -0.02           -0.03             193             203
##    accel_forearm_z magnet_forearm_x magnet_forearm_y magnet_forearm_z
## 1            -215              -17              654              476
## 2            -216              -18              661              473
## 3            -213              -18              658              469
## 4            -214              -16              658              469
## 5            -214              -17              655              473
## 6            -215               -9              660              478
##    classe
## 1      A
## 2      A
## 3      A
## 4      A
## 5      A
## 6      A
```

```
head(clean.test)
```

```
##   roll_belt pitch_belt yaw_belt total_accel_belt gyros_belt_x gyros_belt_y
## 1    123.00      27.00    -4.75               20        -0.50        -0.02
## 2      1.02       4.87   -88.90                4        -0.06        -0.02
## 3      0.87       1.82   -88.50                5         0.05         0.02
## 4    125.00     -41.60   162.00               17         0.11         0.11
## 5      1.35       3.33   -88.60                3         0.03         0.02
## 6     -5.92       1.59   -87.70                4         0.10         0.05
##   gyros_belt_z accel_belt_x accel_belt_y accel_belt_z magnet_belt_x
## 1        -0.46          -38           69         -179           -13
## 2        -0.07          -13           11           39            43
## 3         0.03            1           -1           49            29
## 4        -0.16           46           45         -156           169
## 5         0.00           -8            4           27            33
## 6        -0.13          -11          -16           38            31
##   magnet_belt_y magnet_belt_z roll_arm pitch_arm yaw_arm total_accel_arm
## 1           581          -382     40.7    -27.80     178              10
## 2           636          -309      0.0      0.00       0              38
## 3           631          -312      0.0      0.00       0              44
## 4           608          -304   -109.0     55.00    -142              25
## 5           566          -418     76.1      2.76     102              29
## 6           638          -291      0.0      0.00       0              14
##   gyros_arm_x gyros_arm_y gyros_arm_z accel_arm_x accel_arm_y accel_arm_z
## 1       -1.65        0.48       -0.18          16          38          93
## 2       -1.17        0.85       -0.43        -290         215         -90
## 3        2.10       -1.36        1.13        -341         245         -87
## 4        0.22       -0.51        0.92        -238         -57           6
## 5       -1.96        0.79       -0.54        -197         200         -30
## 6        0.02        0.05       -0.07         -26         130         -19
##   magnet_arm_x magnet_arm_y magnet_arm_z roll_dumbbell pitch_dumbbell
## 1         -326          385          481     -17.73748       24.96085
## 2         -325          447          434      54.47761      -53.69758
## 3         -264          474          413      57.07031      -51.37303
## 4         -173          257          633      43.10927      -30.04885
## 5         -170          275          617    -101.38396      -53.43952
## 6          396          176          516      62.18750      -50.55595
##   yaw_dumbbell total_accel_dumbbell gyros_dumbbell_x gyros_dumbbell_y
## 1    126.23596                    9             0.64             0.06
## 2    -75.51480                   31             0.34             0.05
## 3    -75.20287                   29             0.39             0.14
## 4   -103.32003                   18             0.10            -0.02
## 5    -14.19542                    4             0.29            -0.47
## 6    -71.12063                   29            -0.59             0.80
##   gyros_dumbbell_z accel_dumbbell_x accel_dumbbell_y accel_dumbbell_z
## 1            -0.61               21              -15               81
## 2            -0.71             -153              155             -205
## 3            -0.34             -141              155             -196
## 4             0.05              -51               72             -148
## 5            -0.46              -18              -30               -5
```

```
## 6                1.10             -138              166            -186
##    magnet_dumbbell_x magnet_dumbbell_y magnet_dumbbell_z roll_forearm
## 1                523              -528              -56          141
## 2               -502               388              -36          109
## 3               -506               349               41          131
## 4               -576               238               53            0
## 5               -424               252              312         -176
## 6               -543               262               96          150
##    pitch_forearm yaw_forearm total_accel_forearm gyros_forearm_x
## 1          49.30       156.0                  33            0.74
## 2         -17.60       106.0                  39            1.12
## 3         -32.60        93.0                  34            0.18
## 4           0.00         0.0                  43            1.38
## 5          -2.16       -47.9                  24           -0.75
## 6           1.46        89.7                  43           -0.88
##    gyros_forearm_y gyros_forearm_z accel_forearm_x accel_forearm_y
## 1            -3.34           -0.59            -110             267
## 2            -2.78           -0.18             212             297
## 3            -0.79            0.28             154             271
## 4             0.69            1.80             -92             406
## 5             3.10            0.80             131             -93
## 6             4.26            1.35             230             322
##    accel_forearm_z magnet_forearm_x magnet_forearm_y magnet_forearm_z
## 1             -149             -714              419              617
## 2             -118             -237              791              873
## 3             -129              -51              698              783
## 4              -39             -233              783              521
## 5              172              375             -787               91
## 6             -144             -300              800              884
##    problem_id
## 1          1
## 2          2
## 3          3
## 4          4
## 5          5
## 6          6
```

Correlation Matrix

correlation plot: A quick look at correlations may suggest whether we could simplify the data set further by

identifying pairs of strongly correlated variables:

```
corr <- cor(clean.train[, -length(names(clean.train))])
corr <- round(corr,2)
corr[abs(corr)<0.8]<-0
corrplot(corr, method="circle")
```
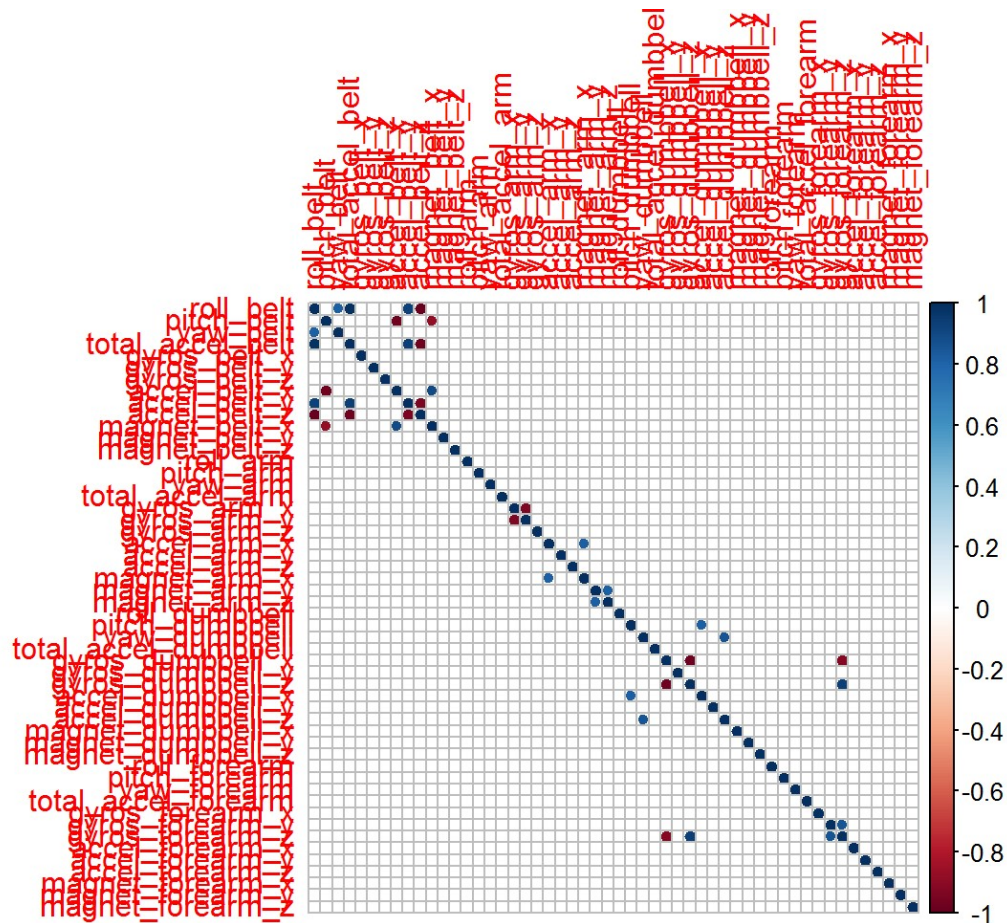

Filter only leave the variables that has the correlation over 80%

Subset data

training set and testing set

```
set.seed(620)
inTrain <- createDataPartition(clean.train$classe, p=0.6, list=FALSE)
training <- clean.train[inTrain,]
testing <- clean.train[-inTrain,]

dim(training)
```

```
## [1] 11776    53
```

```r
dim(testing)
```

```
## [1] 7846   53
```

```r
head(training)
```

```
##    roll_belt pitch_belt yaw_belt total_accel_belt gyros_belt_x
## 6      1.45       8.06    -94.4                3         0.02
## 7      1.42       8.09    -94.4                3         0.02
## 8      1.42       8.13    -94.4                3         0.02
## 13     1.42       8.20    -94.4                3         0.02
## 14     1.42       8.21    -94.4                3         0.02
## 15     1.45       8.20    -94.4                3         0.00
##    gyros_belt_y gyros_belt_z accel_belt_x accel_belt_y accel_belt_z
## 6             0        -0.02          -21            4           21
## 7             0        -0.02          -22            3           21
## 8             0        -0.02          -22            4           21
## 13            0         0.00          -22            4           21
## 14            0        -0.02          -22            4           21
## 15            0         0.00          -21            2           22
##    magnet_belt_x magnet_belt_y magnet_belt_z roll_arm pitch_arm yaw_arm
## 6              0           603          -312     -128      22.0    -161
## 7             -4           599          -311     -128      21.9    -161
## 8             -2           603          -313     -128      21.8    -161
## 13            -3           606          -309     -128      21.4    -161
## 14            -8           598          -310     -128      21.4    -161
## 15            -1           597          -310     -129      21.4    -161
##    total_accel_arm gyros_arm_x gyros_arm_y gyros_arm_z accel_arm_x
## 6               34        0.02       -0.03        0.00        -289
## 7               34        0.00       -0.03        0.00        -289
## 8               34        0.02       -0.02        0.00        -289
## 13              34        0.02       -0.02       -0.02        -287
## 14              34        0.02        0.00       -0.03        -288
## 15              34        0.02        0.00       -0.03        -289
##    accel_arm_y accel_arm_z magnet_arm_x magnet_arm_y magnet_arm_z
## 6          111        -122         -369          342          513
## 7          111        -125         -373          336          509
## 8          111        -124         -372          338          510
## 13         111        -124         -372          338          509
## 14         111        -124         -371          331          523
## 15         111        -124         -374          342          510
##    roll_dumbbell pitch_dumbbell yaw_dumbbell total_accel_dumbbell
## 6       13.38246      -70.81759    -84.46500                   37
## 7       13.12695      -70.24757    -85.09961                   37
## 8       12.75083      -70.34768    -85.09708                   37
## 13      13.38246      -70.81759    -84.46500                   37
## 14      13.41048      -70.99594    -84.28005                   37
## 15      13.07949      -70.67116    -84.69053                   37
##    gyros_dumbbell_x gyros_dumbbell_y gyros_dumbbell_z accel_dumbbell_x
## 6              0.00            -0.02             0.00             -234
## 7              0.00            -0.02             0.00             -232
## 8              0.00            -0.02             0.00             -234
## 13             0.00            -0.02            -0.02             -234
## 14             0.02            -0.02            -0.02             -234
```

```
## 15                 0.00             -0.02               0.00             -234
##    accel_dumbbell_y accel_dumbbell_z magnet_dumbbell_x magnet_dumbbell_y
## 6               48             -269              -558               294
## 7               47             -270              -551               295
## 8               46             -272              -555               300
## 13              48             -269              -552               302
## 14              48             -268              -554               295
## 15              47             -270              -554               294
##    magnet_dumbbell_z roll_forearm pitch_forearm yaw_forearm
## 6               -66         27.9          -63.9        -152
## 7               -70         27.9          -63.9        -152
## 8               -74         27.8          -63.8        -152
## 13              -69         27.2          -63.9        -151
## 14              -68         27.2          -63.9        -151
## 15              -63         27.2          -63.9        -151
##    total_accel_forearm gyros_forearm_x gyros_forearm_y gyros_forearm_z
## 6                   36            0.02           -0.02           -0.03
## 7                   36            0.02            0.00           -0.02
## 8                   36            0.02           -0.02            0.00
## 13                  36            0.00            0.00           -0.03
## 14                  36            0.00           -0.02           -0.03
## 15                  36            0.00           -0.02           -0.02
##    accel_forearm_x accel_forearm_y accel_forearm_z magnet_forearm_x
## 6              193             203            -215               -9
## 7              195             205            -215              -18
## 8              193             205            -213               -9
## 13             193             205            -215              -15
## 14             193             202            -214              -14
## 15             192             201            -214              -16
##    magnet_forearm_y magnet_forearm_z classe
## 6               660              478      A
## 7               659              470      A
## 8               660              474      A
## 13              655              472      A
## 14              659              478      A
## 15              656              472      A
```

```
head(testing)
```

```
##   roll_belt pitch_belt yaw_belt total_accel_belt gyros_belt_x gyros_belt_y
## 1      1.41       8.07    -94.4                3         0.00         0.00
## 2      1.41       8.07    -94.4                3         0.02         0.00
## 3      1.42       8.07    -94.4                3         0.00         0.00
## 4      1.48       8.05    -94.4                3         0.02         0.00
## 5      1.48       8.07    -94.4                3         0.02         0.02
## 9      1.43       8.16    -94.4                3         0.02         0.00
##   gyros_belt_z accel_belt_x accel_belt_y accel_belt_z magnet_belt_x
## 1        -0.02          -21            4           22            -3
## 2        -0.02          -22            4           22            -7
## 3        -0.02          -20            5           23            -2
## 4        -0.03          -22            3           21            -6
## 5        -0.02          -21            2           24            -6
## 9        -0.02          -20            2           24             1
##   magnet_belt_y magnet_belt_z roll_arm pitch_arm yaw_arm total_accel_arm
## 1           599          -313     -128      22.5    -161              34
## 2           608          -311     -128      22.5    -161              34
## 3           600          -305     -128      22.5    -161              34
## 4           604          -310     -128      22.1    -161              34
## 5           600          -302     -128      22.1    -161              34
## 9           602          -312     -128      21.7    -161              34
##   gyros_arm_x gyros_arm_y gyros_arm_z accel_arm_x accel_arm_y accel_arm_z
## 1        0.00        0.00       -0.02        -288         109        -123
## 2        0.02       -0.02       -0.02        -290         110        -125
## 3        0.02       -0.02       -0.02        -289         110        -126
## 4        0.02       -0.03        0.02        -289         111        -123
## 5        0.00       -0.03        0.00        -289         111        -123
## 9        0.02       -0.03       -0.02        -288         109        -122
##   magnet_arm_x magnet_arm_y magnet_arm_z roll_dumbbell pitch_dumbbell
## 1         -368          337          516      13.05217      -70.49400
## 2         -369          337          513      13.13074      -70.63751
## 3         -368          344          513      12.85075      -70.27812
## 4         -372          344          512      13.43120      -70.39379
## 5         -374          337          506      13.37872      -70.42856
## 9         -369          341          518      13.15463      -70.42520
##   yaw_dumbbell total_accel_dumbbell gyros_dumbbell_x gyros_dumbbell_y
## 1    -84.87394                   37                0            -0.02
## 2    -84.71065                   37                0            -0.02
## 3    -85.14078                   37                0            -0.02
## 4    -84.87363                   37                0            -0.02
## 5    -84.85306                   37                0            -0.02
## 9    -84.91563                   37                0            -0.02
##   gyros_dumbbell_z accel_dumbbell_x accel_dumbbell_y accel_dumbbell_z
## 1             0.00             -234               47             -271
## 2             0.00             -233               47             -269
## 3             0.00             -232               46             -270
## 4            -0.02             -232               48             -269
## 5             0.00             -233               48             -270
```

```
## 9                0.00            -232              47             -269
##   magnet_dumbbell_x magnet_dumbbell_y magnet_dumbbell_z roll_forearm
## 1             -559             293              -65        28.4
## 2             -555             296              -64        28.3
## 3             -561             298              -63        28.3
## 4             -552             303              -60        28.1
## 5             -554             292              -68        28.0
## 9             -549             292              -65        27.7
##   pitch_forearm yaw_forearm total_accel_forearm gyros_forearm_x
## 1         -63.9        -153                  36            0.03
## 2         -63.9        -153                  36            0.02
## 3         -63.9        -152                  36            0.03
## 4         -63.9        -152                  36            0.02
## 5         -63.9        -152                  36            0.02
## 9         -63.8        -152                  36            0.03
##   gyros_forearm_y gyros_forearm_z accel_forearm_x accel_forearm_y
## 1            0.00           -0.02             192             203
## 2            0.00           -0.02             192             203
## 3           -0.02            0.00             196             204
## 4           -0.02            0.00             189             206
## 5            0.00           -0.02             189             206
## 9            0.00           -0.02             193             204
##   accel_forearm_z magnet_forearm_x magnet_forearm_y magnet_forearm_z
## 1            -215              -17             654             476
## 2            -216              -18             661             473
## 3            -213              -18             658             469
## 4            -214              -16             658             469
## 5            -214              -17             655             473
## 9            -214              -16             653             476
##   classe
## 1      A
## 2      A
## 3      A
## 4      A
## 5      A
## 9      A
```

Decision Tree

```
DT_modfit <- train(classe ~ ., data = training, method="rpart")


DT_prediction <- predict(DT_modfit, testing)
confusionMatrix(DT_prediction, testing$classe)
```

```
## Confusion Matrix and Statistics
##
##           Reference
## Prediction    A    B    C    D    E
##          A 2057  625  611  539  209
##          B   29  512   43  226  200
##          C  141  381  714  521  416
##          D    0    0    0    0    0
##          E    5    0    0    0  617
##
## Overall Statistics
##
##                Accuracy : 0.4971
##                  95% CI : (0.4859, 0.5082)
##     No Information Rate : 0.2845
##     P-Value [Acc > NIR] : < 2.2e-16
##
##                   Kappa : 0.3432
##  Mcnemar's Test P-Value : NA
##
## Statistics by Class:
##
##                      Class: A Class: B Class: C Class: D Class: E
## Sensitivity            0.9216  0.33729   0.5219   0.0000  0.42788
## Specificity            0.6466  0.92130   0.7748   1.0000  0.99922
## Pos Pred Value         0.5090  0.50693   0.3286      NaN  0.99196
## Neg Pred Value         0.9540  0.85284   0.8847   0.8361  0.88580
## Prevalence             0.2845  0.19347   0.1744   0.1639  0.18379
## Detection Rate         0.2622  0.06526   0.0910   0.0000  0.07864
## Detection Prevalence   0.5150  0.12873   0.2770   0.0000  0.07928
## Balanced Accuracy      0.7841  0.62929   0.6484   0.5000  0.71355
```
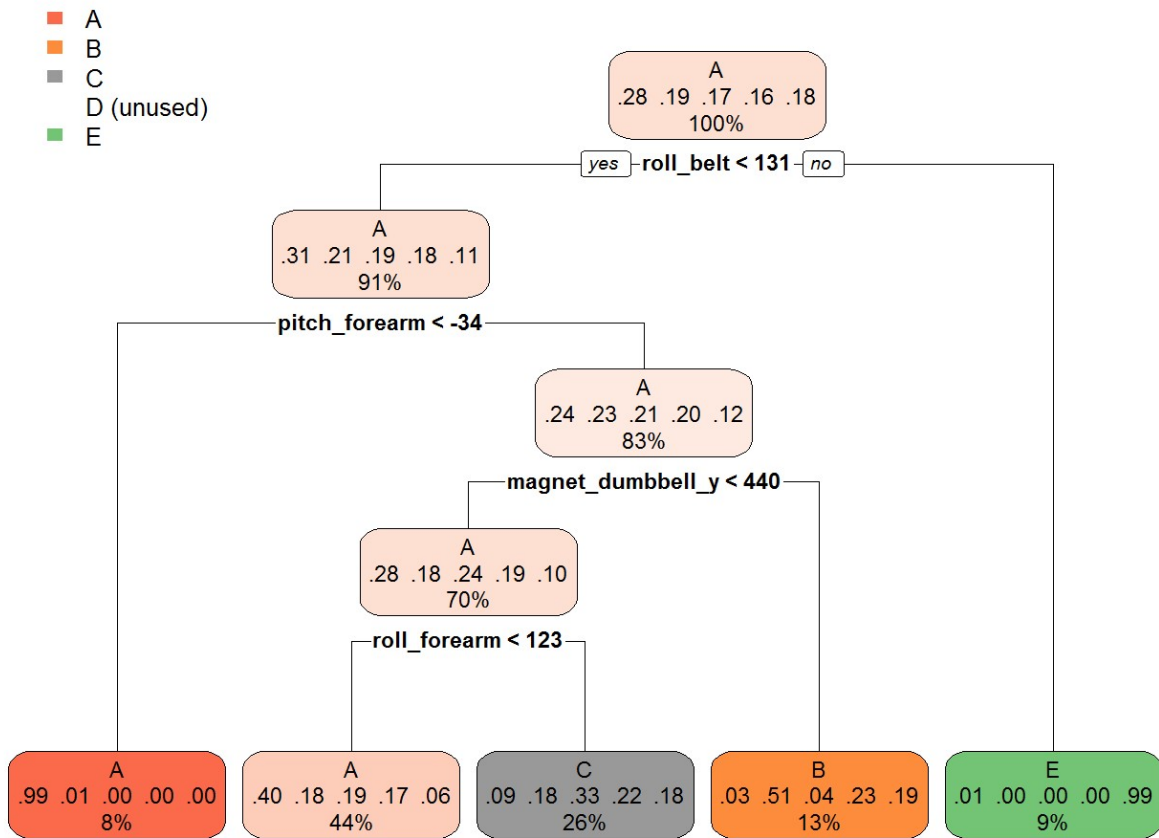
```
library(rpart)
```

```
##
## Attaching package: 'rpart'
```

```
## The following object is masked from 'package:survival':
##
##     solder
```

```
library(rpart.plot)
rpart.plot(DT_modfit$finalModel, roundint=FALSE)
```

The prediction accuracy is 49% and D is unused which is not upto the desired level.

Random Forest Model

```
RF_modfit <- train(classe ~ ., data = training, method = "rf", ntree = 50)
```

predict on test dataset

```
RF_p <- predict(RF_modfit, testing)
RF_pred_conf <- confusionMatrix(RF_p, testing$classe)
RF_pred_conf
```

```
## Confusion Matrix and Statistics
##
##           Reference
## Prediction    A    B    C    D    E
##          A 2228   22    0    0    0
##          B    3 1493    5    0    1
##          C    1    3 1355   16    5
##          D    0    0    8 1270    6
##          E    0    0    0    0 1430
##
## Overall Statistics
##
##                Accuracy : 0.9911
##                  95% CI : (0.9887, 0.993)
##     No Information Rate : 0.2845
##     P-Value [Acc > NIR] : < 2.2e-16
##
##                   Kappa : 0.9887
##  Mcnemar's Test P-Value : NA
##
## Statistics by Class:
##
##                      Class: A Class: B Class: C Class: D Class: E
## Sensitivity            0.9982   0.9835   0.9905   0.9876   0.9917
## Specificity            0.9961   0.9986   0.9961   0.9979   1.0000
## Pos Pred Value         0.9902   0.9940   0.9819   0.9891   1.0000
## Neg Pred Value         0.9993   0.9961   0.9980   0.9976   0.9981
## Prevalence             0.2845   0.1935   0.1744   0.1639   0.1838
## Detection Rate         0.2840   0.1903   0.1727   0.1619   0.1823
## Detection Prevalence   0.2868   0.1914   0.1759   0.1637   0.1823
## Balanced Accuracy      0.9971   0.9911   0.9933   0.9927   0.9958
```

The prediction accuracy is 99% which is satisfied.

Final Predication

predict on test dataset

```
Final_RF_p <- predict(RF_modfit, data.test)
Final_RF_p
```

```
##  [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
```