Title: “Practical Machine Learning - Course Project”

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# Question

6 participants were participated in a barbell lifting in 5 different ways.

Class A: Exactly according to the specification
Class B: Throwing the elbows to the front
Class C: Lifting the dumbbell only halfway
Class D: Lowering the dumbbell only halfway
Class E: Throwing the hips to the front

Class A perform barbell lifts correctly, while Classes B-E perform incorrectly.

By processing data gathered from accelerometers on the belt, forearm, arm, and dumbell of 6 participants in a machine learning algorithm, the question is can the appropriate activity quality (class A-E) can be predicted on testing data?

# Input Data:

Initialize library

```
library(AppliedPredictiveModeling)
library(caret)
library(randomForest)
```

```
library(rattle)
library(rpart.plot)
library(kernlab)
```

Downloading data from source and reading data. Treating empty values as NA.

```
if(!file.exists('pml-training.csv')){
  download.file("https://d396qusza40orc.cloudfront.net/predmachlearn/pml-training.csv",
                destfile='pml-training.csv') }
if(file.exists('pml-training.csv')){
  training <- read.csv('pml-training.csv', na.strings = c("","  ","NA"), header = TRUE) }
str(training)
```

```
## 'data.frame':    19622 obs. of  160 variables:
##  $ X                       : int  1 2 3 4 5 6 7 8 9 10 ...
##  $ user_name               : Factor w/ 6 levels "adelmo","carlitos",..: 2 2 2 2 2 2 2 2 2 2
...
##  $ raw_timestamp_part_1    : int  1323084231 1323084231 1323084231 1323084232 1323084232 132
3084232 1323084232 1323084232 1323084232 1323084232 ...
##  $ raw_timestamp_part_2    : int  788290 808298 820366 120339 196328 304277 368296 440390 48
4323 484434 ...
##  $ cvtd_timestamp          : Factor w/ 20 levels "02/12/2011 13:32",..: 9 9 9 9 9 9 9 9 9 9
...
##  $ new_window              : Factor w/ 2 levels "no","yes": 1 1 1 1 1 1 1 1 1 1 ...
##  $ num_window              : int  11 11 11 12 12 12 12 12 12 12 ...
##  $ roll_belt               : num  1.41 1.41 1.42 1.48 1.48 1.45 1.42 1.42 1.43 1.45 ...
##  $ pitch_belt              : num  8.07 8.07 8.07 8.05 8.07 8.06 8.09 8.13 8.16 8.17 ...
##  $ yaw_belt                : num  -94.4 -94.4 -94.4 -94.4 -94.4 -94.4 -94.4 -94.4 -94.4 -94.
4 ...
##  $ total_accel_belt        : int  3 3 3 3 3 3 3 3 3 3 ...
```

```
##  $ kurtosis_roll_belt      : Factor w/ 396 levels "-0.016850","-0.021024",..: NA NA NA NA NA
NA NA NA NA NA ...
##  $ kurtosis_picth_belt     : Factor w/ 316 levels "-0.021887","-0.060755",..: NA NA NA NA NA
NA NA NA NA NA ...
##  $ kurtosis_yaw_belt       : Factor w/ 1 level "#DIV/0!": NA NA NA NA NA NA NA NA NA NA ...
##  $ skewness_roll_belt      : Factor w/ 394 levels "-0.003095","-0.010002",..: NA NA NA NA NA
NA NA NA NA NA ...
##  $ skewness_roll_belt.1    : Factor w/ 337 levels "-0.005928","-0.005960",..: NA NA NA NA NA
NA NA NA NA NA ...
##  $ skewness_yaw_belt       : Factor w/ 1 level "#DIV/0!": NA NA NA NA NA NA NA NA NA NA ...
##  $ max_roll_belt           : num  NA NA NA NA NA NA NA NA NA NA ...
##  $ max_picth_belt          : int  NA NA NA NA NA NA NA NA NA NA ...
##  $ max_yaw_belt            : Factor w/ 67 levels "-0.1","-0.2",..: NA NA NA NA NA NA NA NA N
A NA ...
##  $ min_roll_belt           : num  NA NA NA NA NA NA NA NA NA NA ...
##  $ min_pitch_belt          : int  NA NA NA NA NA NA NA NA NA NA ...
##  $ min_yaw_belt            : Factor w/ 67 levels "-0.1","-0.2",..: NA NA NA NA NA NA NA NA N
A NA ...
##  $ amplitude_roll_belt     : num  NA NA NA NA NA NA NA NA NA NA ...
##  $ amplitude_pitch_belt    : int  NA NA NA NA NA NA NA NA NA NA ...
##  $ amplitude_yaw_belt      : Factor w/ 3 levels "#DIV/0!","0.00",..: NA NA NA NA NA NA NA NA
NA NA ...
##  $ var_total_accel_belt    : num  NA NA NA NA NA NA NA NA NA NA ...
##  $ avg_roll_belt           : num  NA NA NA NA NA NA NA NA NA NA ...
##  $ stddev_roll_belt        : num  NA NA NA NA NA NA NA NA NA NA ...
##  $ var_roll_belt           : num  NA NA NA NA NA NA NA NA NA NA ...
##  $ avg_pitch_belt          : num  NA NA NA NA NA NA NA NA NA NA ...
##  $ stddev_pitch_belt       : num  NA NA NA NA NA NA NA NA NA NA ...
##  $ var_pitch_belt          : num  NA NA NA NA NA NA NA NA NA NA ...
##  $ avg_yaw_belt            : num  NA NA NA NA NA NA NA NA NA NA ...
##  $ stddev_yaw_belt         : num  NA NA NA NA NA NA NA NA NA NA ...
```

```
##  $ var_yaw_belt            : num  NA NA NA NA NA NA NA NA NA NA ...
##  $ gyros_belt_x            : num  0 0.02 0 0.02 0.02 0.02 0.02 0.02 0.02 0.03 ...
##  $ gyros_belt_y            : num  0 0 0 0 0.02 0 0 0 0 0 ...
##  $ gyros_belt_z            : num  -0.02 -0.02 -0.02 -0.03 -0.02 -0.02 -0.02 -0.02 -0.02 0 ..
.
##  $ accel_belt_x            : int  -21 -22 -20 -22 -21 -21 -22 -22 -20 -21 ...
##  $ accel_belt_y            : int  4 4 5 3 2 4 3 4 2 4 ...
##  $ accel_belt_z            : int  22 22 23 21 24 21 21 21 24 22 ...
##  $ magnet_belt_x           : int  -3 -7 -2 -6 -6 0 -4 -2 1 -3 ...
##  $ magnet_belt_y           : int  599 608 600 604 600 603 599 603 602 609 ...
##  $ magnet_belt_z           : int  -313 -311 -305 -310 -302 -312 -311 -313 -312 -308 ...
##  $ roll_arm                : num  -128 -128 -128 -128 -128 -128 -128 -128 -128 -128 ...
##  $ pitch_arm               : num  22.5 22.5 22.5 22.1 22.1 22 21.9 21.8 21.7 21.6 ...
##  $ yaw_arm                 : num  -161 -161 -161 -161 -161 -161 -161 -161 -161 -161 ...
##  $ total_accel_arm         : int  34 34 34 34 34 34 34 34 34 34 ...
##  $ var_accel_arm           : num  NA NA NA NA NA NA NA NA NA NA ...
##  $ avg_roll_arm            : num  NA NA NA NA NA NA NA NA NA NA ...
##  $ stddev_roll_arm         : num  NA NA NA NA NA NA NA NA NA NA ...
##  $ var_roll_arm            : num  NA NA NA NA NA NA NA NA NA NA ...
##  $ avg_pitch_arm           : num  NA NA NA NA NA NA NA NA NA NA ...
##  $ stddev_pitch_arm        : num  NA NA NA NA NA NA NA NA NA NA ...
##  $ var_pitch_arm           : num  NA NA NA NA NA NA NA NA NA NA ...
##  $ avg_yaw_arm             : num  NA NA NA NA NA NA NA NA NA NA ...
##  $ stddev_yaw_arm          : num  NA NA NA NA NA NA NA NA NA NA ...
##  $ var_yaw_arm             : num  NA NA NA NA NA NA NA NA NA NA ...
##  $ gyros_arm_x             : num  0 0.02 0.02 0.02 0 0.02 0 0.02 0.02 0.02 ...
##  $ gyros_arm_y             : num  0 -0.02 -0.02 -0.03 -0.03 -0.03 -0.03 -0.02 -0.03 -0.03 ..
.
##  $ gyros_arm_z             : num  -0.02 -0.02 -0.02 0.02 0 0 0 0 -0.02 -0.02 ...
##  $ accel_arm_x             : int  -288 -290 -289 -289 -289 -289 -289 -289 -288 -288 ...
##  $ accel_arm_y             : int  109 110 110 111 111 111 111 111 109 110 ...
```

```
##  $ accel_arm_z             : int  -123 -125 -126 -123 -123 -122 -125 -124 -122 -124 ...
##  $ magnet_arm_x            : int  -368 -369 -368 -372 -374 -369 -373 -372 -369 -376 ...
##  $ magnet_arm_y            : int  337 337 344 344 337 342 336 338 341 334 ...
##  $ magnet_arm_z            : int  516 513 513 512 506 513 509 510 518 516 ...
##  $ kurtosis_roll_arm       : Factor w/ 329 levels "-0.02438","-0.04190",..: NA NA NA NA NA N
A NA NA NA NA ...
##  $ kurtosis_picth_arm      : Factor w/ 327 levels "-0.00484","-0.01311",..: NA NA NA NA NA N
A NA NA NA NA ...
##  $ kurtosis_yaw_arm        : Factor w/ 394 levels "-0.01548","-0.01749",..: NA NA NA NA NA N
A NA NA NA NA ...
##  $ skewness_roll_arm       : Factor w/ 330 levels "-0.00051","-0.00696",..: NA NA NA NA NA N
A NA NA NA NA ...
##  $ skewness_pitch_arm      : Factor w/ 327 levels "-0.00184","-0.01185",..: NA NA NA NA NA N
A NA NA NA NA ...
##  $ skewness_yaw_arm        : Factor w/ 394 levels "-0.00311","-0.00562",..: NA NA NA NA NA N
A NA NA NA NA ...
##  $ max_roll_arm            : num  NA NA NA NA NA NA NA NA NA NA ...
##  $ max_picth_arm           : num  NA NA NA NA NA NA NA NA NA NA ...
##  $ max_yaw_arm             : int  NA NA NA NA NA NA NA NA NA NA ...
##  $ min_roll_arm            : num  NA NA NA NA NA NA NA NA NA NA ...
##  $ min_pitch_arm           : num  NA NA NA NA NA NA NA NA NA NA ...
##  $ min_yaw_arm             : int  NA NA NA NA NA NA NA NA NA NA ...
##  $ amplitude_roll_arm      : num  NA NA NA NA NA NA NA NA NA NA ...
##  $ amplitude_pitch_arm     : num  NA NA NA NA NA NA NA NA NA NA ...
##  $ amplitude_yaw_arm       : int  NA NA NA NA NA NA NA NA NA NA ...
##  $ roll_dumbbell           : num  13.1 13.1 12.9 13.4 13.4 ...
##  $ pitch_dumbbell          : num  -70.5 -70.6 -70.3 -70.4 -70.4 ...
##  $ yaw_dumbbell            : num  -84.9 -84.7 -85.1 -84.9 -84.9 ...
##  $ kurtosis_roll_dumbbell  : Factor w/ 397 levels "-0.0035","-0.0073",..: NA NA NA NA NA NA
NA NA NA NA ...
##  $ kurtosis_picth_dumbbell : Factor w/ 400 levels "-0.0163","-0.0233",..: NA NA NA NA NA NA
```

```
NA NA NA NA ...
##  $ kurtosis_yaw_dumbbell   : Factor w/ 1 level "#DIV/0!": NA NA NA NA NA NA NA NA NA NA ...
##  $ skewness_roll_dumbbell  : Factor w/ 400 levels "-0.0082","-0.0096",..: NA NA NA NA NA NA
NA NA NA NA ...
##  $ skewness_pitch_dumbbell : Factor w/ 401 levels "-0.0053","-0.0084",..: NA NA NA NA NA NA
NA NA NA NA ...
##  $ skewness_yaw_dumbbell   : Factor w/ 1 level "#DIV/0!": NA NA NA NA NA NA NA NA NA NA ...
##  $ max_roll_dumbbell       : num  NA NA NA NA NA NA NA NA NA NA ...
##  $ max_picth_dumbbell      : num  NA NA NA NA NA NA NA NA NA NA ...
##  $ max_yaw_dumbbell        : Factor w/ 72 levels "-0.1","-0.2",..: NA NA NA NA NA NA NA NA N
A NA ...
##  $ min_roll_dumbbell       : num  NA NA NA NA NA NA NA NA NA NA ...
##  $ min_pitch_dumbbell      : num  NA NA NA NA NA NA NA NA NA NA ...
##  $ min_yaw_dumbbell        : Factor w/ 72 levels "-0.1","-0.2",..: NA NA NA NA NA NA NA NA N
A NA ...
##  $ amplitude_roll_dumbbell : num  NA NA NA NA NA NA NA NA NA NA ...
##   [list output truncated]
```

```
if(!file.exists('pml-testing.csv')){
  download.file("https://d396qusza40orc.cloudfront.net/predmachlearn/pml-testing.csv",
                destfile='pml-testing.csv') }
if(file.exists('pml-testing.csv')){
  testing <- read.csv('pml-testing.csv', na.strings = c("","  ","NA"), header = TRUE) }
str(testing)
```

```
## 'data.frame':    20 obs. of  160 variables:
##  $ X                       : int  1 2 3 4 5 6 7 8 9 10 ...
##  $ user_name               : Factor w/ 6 levels "adelmo","carlitos",..: 6 5 5 1 4 5 5 5 2 3
...
##  $ raw_timestamp_part_1    : int  1323095002 1322673067 1322673075 1322832789 1322489635 132
```

```
2673149 1322673128 1322673076 1323084240 1322837822 ...
##  $ raw_timestamp_part_2    : int  868349 778725 342967 560311 814776 510661 766645 54671 916
313 384285 ...
##  $ cvtd_timestamp          : Factor w/ 11 levels "02/12/2011 13:33",..: 5 10 10 1 6 11 11 10
3 2 ...
##  $ new_window              : Factor w/ 1 level "no": 1 1 1 1 1 1 1 1 1 1 ...
##  $ num_window              : int  74 431 439 194 235 504 485 440 323 664 ...
##  $ roll_belt               : num  123 1.02 0.87 125 1.35 -5.92 1.2 0.43 0.93 114 ...
##  $ pitch_belt              : num  27 4.87 1.82 -41.6 3.33 1.59 4.44 4.15 6.72 22.4 ...
##  $ yaw_belt                : num  -4.75 -88.9 -88.5 162 -88.6 -87.7 -87.3 -88.5 -93.7 -13.1
...
##  $ total_accel_belt        : int  20 4 5 17 3 4 4 4 4 18 ...
##  $ kurtosis_roll_belt      : logi  NA NA NA NA NA NA ...
##  $ kurtosis_picth_belt     : logi  NA NA NA NA NA NA ...
##  $ kurtosis_yaw_belt       : logi  NA NA NA NA NA NA ...
##  $ skewness_roll_belt      : logi  NA NA NA NA NA NA ...
##  $ skewness_roll_belt.1    : logi  NA NA NA NA NA NA ...
##  $ skewness_yaw_belt       : logi  NA NA NA NA NA NA ...
##  $ max_roll_belt           : logi  NA NA NA NA NA NA ...
##  $ max_picth_belt          : logi  NA NA NA NA NA NA ...
##  $ max_yaw_belt            : logi  NA NA NA NA NA NA ...
##  $ min_roll_belt           : logi  NA NA NA NA NA NA ...
##  $ min_pitch_belt          : logi  NA NA NA NA NA NA ...
##  $ min_yaw_belt            : logi  NA NA NA NA NA NA ...
##  $ amplitude_roll_belt     : logi  NA NA NA NA NA NA ...
##  $ amplitude_pitch_belt    : logi  NA NA NA NA NA NA ...
##  $ amplitude_yaw_belt      : logi  NA NA NA NA NA NA ...
##  $ var_total_accel_belt    : logi  NA NA NA NA NA NA ...
##  $ avg_roll_belt           : logi  NA NA NA NA NA NA ...
##  $ stddev_roll_belt        : logi  NA NA NA NA NA NA ...
##  $ var_roll_belt           : logi  NA NA NA NA NA NA ...
```

```
##  $ avg_pitch_belt          : logi  NA NA NA NA NA NA ...
##  $ stddev_pitch_belt       : logi  NA NA NA NA NA NA ...
##  $ var_pitch_belt          : logi  NA NA NA NA NA NA ...
##  $ avg_yaw_belt            : logi  NA NA NA NA NA NA ...
##  $ stddev_yaw_belt         : logi  NA NA NA NA NA NA ...
##  $ var_yaw_belt            : logi  NA NA NA NA NA NA ...
##  $ gyros_belt_x            : num  -0.5 -0.06 0.05 0.11 0.03 0.1 -0.06 -0.18 0.1 0.14 ...
##  $ gyros_belt_y            : num  -0.02 -0.02 0.02 0.11 0.02 0.05 0 -0.02 0 0.11 ...
##  $ gyros_belt_z            : num  -0.46 -0.07 0.03 -0.16 0 -0.13 0 -0.03 -0.02 -0.16 ...
##  $ accel_belt_x            : int  -38 -13 1 46 -8 -11 -14 -10 -15 -25 ...
##  $ accel_belt_y            : int  69 11 -1 45 4 -16 2 -2 1 63 ...
##  $ accel_belt_z            : int  -179 39 49 -156 27 38 35 42 32 -158 ...
##  $ magnet_belt_x           : int  -13 43 29 169 33 31 50 39 -6 10 ...
##  $ magnet_belt_y           : int  581 636 631 608 566 638 622 635 600 601 ...
##  $ magnet_belt_z           : int  -382 -309 -312 -304 -418 -291 -315 -305 -302 -330 ...
##  $ roll_arm                : num  40.7 0 0 -109 76.1 0 0 0 -137 -82.4 ...
##  $ pitch_arm               : num  -27.8 0 0 55 2.76 0 0 0 11.2 -63.8 ...
##  $ yaw_arm                 : num  178 0 0 -142 102 0 0 0 -167 -75.3 ...
##  $ total_accel_arm         : int  10 38 44 25 29 14 15 22 34 32 ...
##  $ var_accel_arm           : logi  NA NA NA NA NA NA ...
##  $ avg_roll_arm            : logi  NA NA NA NA NA NA ...
##  $ stddev_roll_arm         : logi  NA NA NA NA NA NA ...
##  $ var_roll_arm            : logi  NA NA NA NA NA NA ...
##  $ avg_pitch_arm           : logi  NA NA NA NA NA NA ...
##  $ stddev_pitch_arm        : logi  NA NA NA NA NA NA ...
##  $ var_pitch_arm           : logi  NA NA NA NA NA NA ...
##  $ avg_yaw_arm             : logi  NA NA NA NA NA NA ...
##  $ stddev_yaw_arm          : logi  NA NA NA NA NA NA ...
##  $ var_yaw_arm             : logi  NA NA NA NA NA NA ...
##  $ gyros_arm_x             : num  -1.65 -1.17 2.1 0.22 -1.96 0.02 2.36 -3.71 0.03 0.26 ...
##  $ gyros_arm_y             : num  0.48 0.85 -1.36 -0.51 0.79 0.05 -1.01 1.85 -0.02 -0.5 ...
```

```
##  $ gyros_arm_z             : num  -0.18 -0.43 1.13 0.92 -0.54 -0.07 0.89 -0.69 -0.02 0.79 ..
.
##  $ accel_arm_x             : int  16 -290 -341 -238 -197 -26 99 -98 -287 -301 ...
##  $ accel_arm_y             : int  38 215 245 -57 200 130 79 175 111 -42 ...
##  $ accel_arm_z             : int  93 -90 -87 6 -30 -19 -67 -78 -122 -80 ...
##  $ magnet_arm_x            : int  -326 -325 -264 -173 -170 396 702 535 -367 -420 ...
##  $ magnet_arm_y            : int  385 447 474 257 275 176 15 215 335 294 ...
##  $ magnet_arm_z            : int  481 434 413 633 617 516 217 385 520 493 ...
##  $ kurtosis_roll_arm       : logi  NA NA NA NA NA NA ...
##  $ kurtosis_picth_arm      : logi  NA NA NA NA NA NA ...
##  $ kurtosis_yaw_arm        : logi  NA NA NA NA NA NA ...
##  $ skewness_roll_arm       : logi  NA NA NA NA NA NA ...
##  $ skewness_pitch_arm      : logi  NA NA NA NA NA NA ...
##  $ skewness_yaw_arm        : logi  NA NA NA NA NA NA ...
##  $ max_roll_arm            : logi  NA NA NA NA NA NA ...
##  $ max_picth_arm           : logi  NA NA NA NA NA NA ...
##  $ max_yaw_arm             : logi  NA NA NA NA NA NA ...
##  $ min_roll_arm            : logi  NA NA NA NA NA NA ...
##  $ min_pitch_arm           : logi  NA NA NA NA NA NA ...
##  $ min_yaw_arm             : logi  NA NA NA NA NA NA ...
##  $ amplitude_roll_arm      : logi  NA NA NA NA NA NA ...
##  $ amplitude_pitch_arm     : logi  NA NA NA NA NA NA ...
##  $ amplitude_yaw_arm       : logi  NA NA NA NA NA NA ...
##  $ roll_dumbbell           : num  -17.7 54.5 57.1 43.1 -101.4 ...
##  $ pitch_dumbbell          : num  25 -53.7 -51.4 -30 -53.4 ...
##  $ yaw_dumbbell            : num  126.2 -75.5 -75.2 -103.3 -14.2 ...
##  $ kurtosis_roll_dumbbell  : logi  NA NA NA NA NA NA ...
##  $ kurtosis_picth_dumbbell : logi  NA NA NA NA NA NA ...
##  $ kurtosis_yaw_dumbbell   : logi  NA NA NA NA NA NA ...
##  $ skewness_roll_dumbbell  : logi  NA NA NA NA NA NA ...
##  $ skewness_pitch_dumbbell : logi  NA NA NA NA NA NA ...
```

```
##  $ skewness_yaw_dumbbell   : logi  NA NA NA NA NA NA ...
##  $ max_roll_dumbbell       : logi  NA NA NA NA NA NA ...
##  $ max_picth_dumbbell      : logi  NA NA NA NA NA NA ...
##  $ max_yaw_dumbbell        : logi  NA NA NA NA NA NA ...
##  $ min_roll_dumbbell       : logi  NA NA NA NA NA NA ...
##  $ min_pitch_dumbbell      : logi  NA NA NA NA NA NA ...
##  $ min_yaw_dumbbell        : logi  NA NA NA NA NA NA ...
##  $ amplitude_roll_dumbbell : logi  NA NA NA NA NA NA ...
##   [list output truncated]
```

# Features

Finding the columns not matching between training and testing sets

```
ind <- which(is.na(pmatch(names(training), names(testing))))
names(training)[ind]
```

```
## [1] "classe"
```

```
names(testing)[ind]
```

```
## [1] "problem_id"
```

Perform machine learning algorithm to column “classe” in training set to predict testing data.

For machine learning algorithm to predict effectively, drop the columns which has lot of NA’s and also drop first 7 columns which consist of personal information regarding participants.

```
na_count <-sapply(training, function(y) sum(length(which(is.na(y)))))
na_count <- data.frame(na_count)
nonzeroind <- which(na_count == 0)
nonzeroind <- nonzeroind[8:length(nonzeroind)]
```

Following columns are considered in the training set for perdiction algorithm.

```
training <- as.data.frame(training[,nonzeroind], drop = FALSE)
names(training)
```

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

Corresponding columns in the testing set.

```
testing <- as.data.frame(testing[,nonzeroind], drop = FALSE)
names(testing)
```

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

Check for covariates that have virtually no variability

```
nsv <- nearZeroVar(training, saveMetrics = TRUE)
nsv
```

```
##                     freqRatio percentUnique zeroVar   nzv
## roll_belt            1.101904     6.7781062   FALSE FALSE
```

```
## pitch_belt            1.036082     9.3772296   FALSE FALSE
## yaw_belt              1.058480     9.9734991   FALSE FALSE
## total_accel_belt      1.063160     0.1477933   FALSE FALSE
## gyros_belt_x          1.058651     0.7134849   FALSE FALSE
## gyros_belt_y          1.144000     0.3516461   FALSE FALSE
## gyros_belt_z          1.066214     0.8612782   FALSE FALSE
## accel_belt_x          1.055412     0.8357966   FALSE FALSE
## accel_belt_y          1.113725     0.7287738   FALSE FALSE
## accel_belt_z          1.078767     1.5237998   FALSE FALSE
## magnet_belt_x         1.090141     1.6664968   FALSE FALSE
## magnet_belt_y         1.099688     1.5187035   FALSE FALSE
## magnet_belt_z         1.006369     2.3290184   FALSE FALSE
## roll_arm             52.338462    13.5256345   FALSE FALSE
## pitch_arm            87.256410    15.7323412   FALSE FALSE
## yaw_arm              33.029126    14.6570176   FALSE FALSE
## total_accel_arm       1.024526     0.3363572   FALSE FALSE
## gyros_arm_x           1.015504     3.2769341   FALSE FALSE
## gyros_arm_y           1.454369     1.9162165   FALSE FALSE
## gyros_arm_z           1.110687     1.2638875   FALSE FALSE
## accel_arm_x           1.017341     3.9598410   FALSE FALSE
## accel_arm_y           1.140187     2.7367241   FALSE FALSE
## accel_arm_z           1.128000     4.0362858   FALSE FALSE
## magnet_arm_x          1.000000     6.8239731   FALSE FALSE
## magnet_arm_y          1.056818     4.4439914   FALSE FALSE
## magnet_arm_z          1.036364     6.4468454   FALSE FALSE
## roll_dumbbell         1.022388    84.2065029   FALSE FALSE
## pitch_dumbbell        2.277372    81.7449801   FALSE FALSE
## yaw_dumbbell          1.132231    83.4828254   FALSE FALSE
## total_accel_dumbbell  1.072634     0.2191418   FALSE FALSE
## gyros_dumbbell_x      1.003268     1.2282132   FALSE FALSE
## gyros_dumbbell_y      1.264957     1.4167771   FALSE FALSE
```

```
## gyros_dumbbell_z      1.060100     1.0498420   FALSE FALSE
## accel_dumbbell_x      1.018018     2.1659362   FALSE FALSE
## accel_dumbbell_y      1.053061     2.3748853   FALSE FALSE
## accel_dumbbell_z      1.133333     2.0894914   FALSE FALSE
## magnet_dumbbell_x     1.098266     5.7486495   FALSE FALSE
## magnet_dumbbell_y     1.197740     4.3012945   FALSE FALSE
## magnet_dumbbell_z     1.020833     3.4451126   FALSE FALSE
## roll_forearm         11.589286    11.0895933   FALSE FALSE
## pitch_forearm        65.983051    14.8557741   FALSE FALSE
## yaw_forearm          15.322835    10.1467740   FALSE FALSE
## total_accel_forearm   1.128928     0.3567424   FALSE FALSE
## gyros_forearm_x       1.059273     1.5187035   FALSE FALSE
## gyros_forearm_y       1.036554     3.7763735   FALSE FALSE
## gyros_forearm_z       1.122917     1.5645704   FALSE FALSE
## accel_forearm_x       1.126437     4.0464784   FALSE FALSE
## accel_forearm_y       1.059406     5.1116094   FALSE FALSE
## accel_forearm_z       1.006250     2.9558659   FALSE FALSE
## magnet_forearm_x      1.012346     7.7667924   FALSE FALSE
## magnet_forearm_y      1.246914     9.5403119   FALSE FALSE
## magnet_forearm_z      1.000000     8.5771073   FALSE FALSE
## classe                1.469581     0.0254816   FALSE FALSE
```

Non zero variance is FALSE for all columns considered in the training set. Hence there is no need to eliminate any covariates due to lack of variablity.

# Machine Learning Algorithm

Training set has 19,622 observations (large in size). It will be time consuming to perform algorithm on large data set.

**Step 1.** For classe variable, divide the given training set into 4 almost equal parts (part1, part2, part3, part4).
**Step 2.** Split each part into a training (60%) (part1.train, part2.train, part3.train, part4.train) and testing set (40%)

(part1.test, part2.test, part3.test, part4.test).
**Step 3.** Construct regression model using train on each training set (part1.train, part2.train, part3.train, part4.train) by defining method and cross validation.
**Step 4.** Predict respective testing set (part1.test, part2.test, part3.test, part4.test) and calculate the accuracy of prediction.
**Step 5.** Alter the method used for regression analysis, based on the accuracy for predicting testing sets.
**Step 6.** After achieving desired accuracy, predcit the given testing set (20 Quiz prediction) using all four regression models and compare the results of prediction and accuracy.

**Step 1.**

```
set.seed(2121)
partition <- createDataPartition(y = training$classe, p = 0.25, list = FALSE)
part1 <- training[partition,]
rest<- training[-partition,]
set.seed(2121)
partition <- createDataPartition(y = rest$classe, p = 0.33, list = FALSE)
part2 <- rest[partition,]
rest <- rest[-partition,]
set.seed(2121)
partition <- createDataPartition(y = rest$classe, p = 0.5, list = FALSE)
part3 <- rest[partition,]
part4 <- rest[-partition,]
```

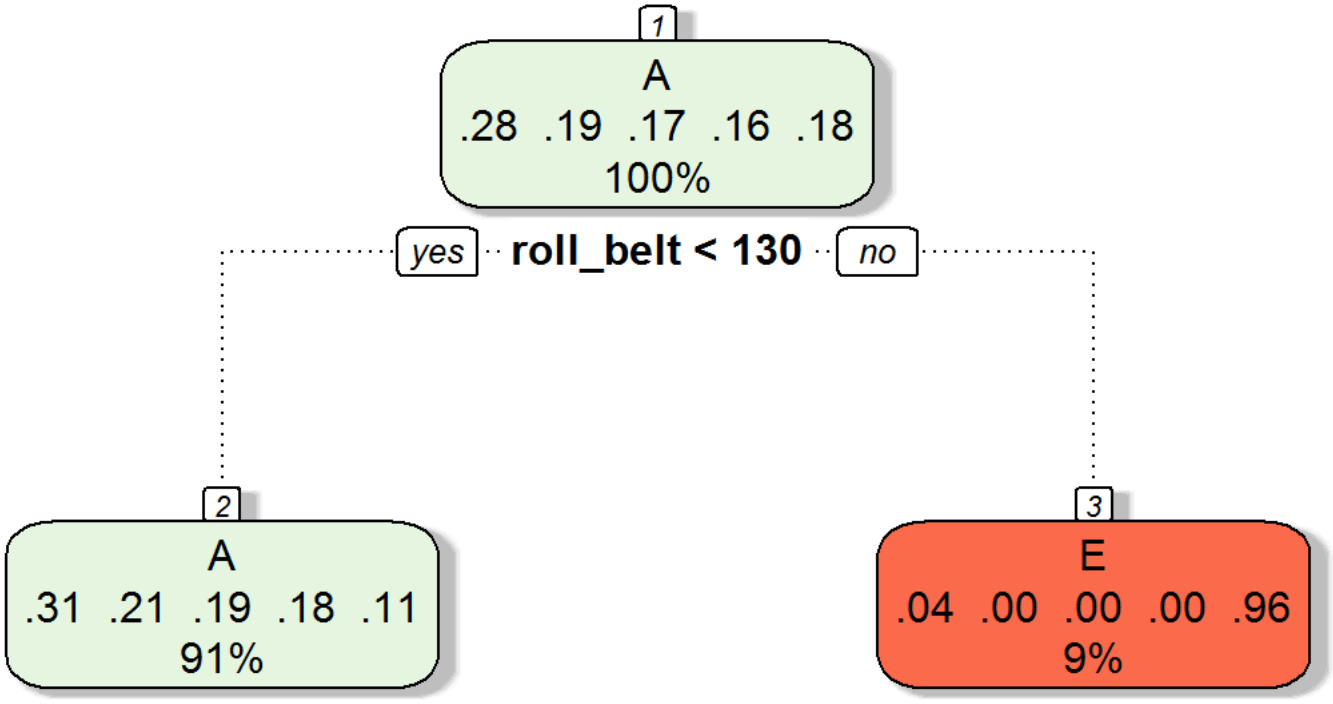
**Step 2.**

```
set.seed(2121)
inTrain <- createDataPartition(y = part1$classe, p = 0.6, list = FALSE)
part1.train <- part1[inTrain,]
part1.test <- part1[-inTrain,]
set.seed(2121)
inTrain <- createDataPartition(y = part2$classe, p = 0.6, list = FALSE)
```

```
part2.train <- part2[inTrain,]
part2.test <- part2[-inTrain,]
set.seed(2121)
inTrain <- createDataPartition(y = part3$classe, p = 0.6, list = FALSE)
part3.train <- part3[inTrain,]
part3.test <- part3[-inTrain,]
set.seed(2121)
inTrain <- createDataPartition(y = part4$classe, p = 0.6, list = FALSE)
part4.train <- part4[inTrain,]
part4.test <- part4[-inTrain,]
```

**Step 3.**

```
set.seed(2121)
part1.modFit <- train(part1.train$classe ~., method = "rpart", data = part1.train,
                      trControl = trainControl(method = "cv", number = 3))
fancyRpartPlot(part1.modFit$finalModel)
```

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```
part1.pred <- predict(part1.modFit, part1.test)
confusionMatrix(part1.pred,part1.test$classe)$overall['Accuracy']
```

```
##  Accuracy
## 0.3686894
```

Accuracy is just 37% using method = “rpart” and cross validation. Accuracy is pretty low. We can try another method called randomForest, method = “rf”.

**Step 4.**

Prediction of given testing set (20 Quiz Prediction) using part1.train

```
set.seed(2121)
part1.modFit <- train(part1.train$classe ~., method = "rf", data = part1.train,
                      trControl = trainControl(method = "cv", number = 3))
part1.pred <- predict(part1.modFit, part1.test)
part1.accuracy <- confusionMatrix(part1.pred,part1.test$classe)$overall['Accuracy']
part1.accuracy
```

```
##  Accuracy
## 0.9602244
```

```
pred1 <- predict(part1.modFit, newdata = testing)
pred1
```

```
##  [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
```

Prediction of given testing set (20 Quiz Prediction) using part2.train

```
set.seed(2121)
part2.modFit <- train(part2.train$classe ~., method = "rf", data = part2.train,
```

```
                      trControl = trainControl(method = "cv", number = 3))
part2.pred <- predict(part2.modFit, part2.test)
part2.accuracy <- confusionMatrix(part2.pred,part2.test$classe)$overall['Accuracy']
part2.accuracy
```

```
##  Accuracy
## 0.9665121
```

```
pred2 <- predict(part2.modFit, newdata = testing)
pred2
```

```
##  [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
```

Prediction of given testing set (20 Quiz Prediction) using part3.train

```
set.seed(2121)
part3.modFit <- train(part3.train$classe ~., method = "rf", data = part3.train,
                      trControl = trainControl(method = "cv", number = 3))
part3.pred <- predict(part3.modFit, part3.test)
part3.accuracy <- confusionMatrix(part3.pred,part3.test$classe)$overall['Accuracy']
part3.accuracy
```

```
##  Accuracy
## 0.9563452
```

```
pred3 <- predict(part3.modFit, newdata = testing)
pred3
```

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

Prediction of given testing set (20 Quiz Prediction) using part4.train

```
set.seed(2121)
part4.modFit <- train(part4.train$classe ~., method = "rf", data = part4.train,
                      trControl = trainControl(method = "cv", number = 3))
part4.pred <- predict(part4.modFit, part4.test)
part4.accuracy <- confusionMatrix(part4.pred,part4.test$classe)$overall['Accuracy']
part4.accuracy
```

```
## Accuracy
## 0.960386
```

```
pred4 <- predict(part4.modFit, newdata = testing)
pred4
```

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

Comparing predictions from each part of the training data set.

```
pred <- data.frame(pred1,pred2,pred3,pred4)
names(pred) <- c("Data.part1", "Data.part2", "Data.part3", "Data.part4")
pred
```

```
##    Data.part1 Data.part2 Data.part3 Data.part4
## 1           B          B          B          B
## 2           A          A          A          A
## 3           B          B          A          A
## 4           A          A          A          A
## 5           A          A          A          A
## 6           E          E          E          E
## 7           D          D          D          D
## 8           B          B          B          B
## 9           A          A          A          A
## 10          A          A          A          A
## 11          B          B          B          B
## 12          C          C          C          C
## 13          B          B          B          B
## 14          A          A          A          A
## 15          E          E          E          E
## 16          E          E          E          E
## 17          A          A          A          A
## 18          B          B          B          B
## 19          B          B          B          A
## 20          B          B          B          B
```

Calculate accuracy of prediction given by each part of training set and calculate “out of sample error”

```
Accuracy <- data.frame(part1.accuracy, part2.accuracy, part3.accuracy, part4.accuracy)
Accuracy <- round(Accuracy * 100)
OutofSampleError <- 100 - Accuracy
Accuracy <- paste(Accuracy,'%',sep = "")
```

Accuracy of prediction by each part of training data set is:

```
Accuracy
```

```
## [1] "96%" "97%" "96%" "96%"
```

# Out of Sample Error

Out of sample error for each part of training data set is:

```
OutofSampleError <- paste(OutofSampleError,'%',sep = "")
OutofSampleError
```

```
## [1] "4%" "3%" "4%" "4%"
```

# Conclusion

Prediction for 20 test data is

```
pred1
```

```
##  [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
```