

Practical Machine Learning - Final Project

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Problem Statement

People are using devices such as Jawbone Up, Nike FuelBand, and Fitbit to collect data about personal activity. Folks take measurements about themselves regularly to improve their health, to find patterns in their behavior, or because they are tech geeks. This data quantifies how much of a particular activity they do, but rarely quantifies how well they do it. We will use the data from accelerometers on the belt, forearm, arm, and dumbbell of 6 participants to quantify the quality of their exercises. They were asked to perform barbell lifts correctly and incorrectly in 5 different ways. More information is available from the website here: <http://groupware.les.inf.puc-rio.br/har> (see the section on the Weight Lifting Exercise Dataset).

The training data for this project are available here:

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

The test data are available here:

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

The data for this project come from this source: <http://groupware.les.inf.puc-rio.br/har> and is being acknowledged in this assignment.

Reading in Data

read the dataframes, setting blank values as NA, if I want to impute later

```
training <- read.csv("https://d396qusza40orc.cloudfront.net/predmachlearn/pml-training.csv",
                    check.names = TRUE, na.strings=c("NA",""),
                    header=TRUE, stringsAsFactors=FALSE)
testing <- read.csv("https://d396qusza40orc.cloudfront.net/predmachlearn/pml-testing.csv",
                   check.names = TRUE, na.strings=c("NA",""),
                   header=TRUE, stringsAsFactors=FALSE)
```

get some info about the dataframes

```
summary(training)
```

```
##           X           user_name      raw_timestamp_part_1
## Min.      :    1   Length:19622      Min.      :1.322e+09
## 1st Qu.: 4906   Class :character      1st Qu.:1.323e+09
## Median : 9812   Mode  :character      Median :1.323e+09
## Mean      : 9812                                Mean      :1.323e+09
## 3rd Qu.:14717                                3rd Qu.:1.323e+09
## Max.      :19622                                Max.      :1.323e+09
##
## raw_timestamp_part_2  cvtd_timestamp      new_window
## Min.      :   294      Length:19622      Length:19622
```

```

## 1st Qu.:252912      Class :character  Class :character
## Median :496380      Mode  :character  Mode  :character
## Mean    :500656
## 3rd Qu.:751891
## Max.    :998801
##
##      num_window      roll_belt      pitch_belt      yaw_belt
## Min.   : 1.0      Min.   : -28.90      Min.   : -55.8000      Min.   : -180.00
## 1st Qu.:222.0      1st Qu.:  1.10      1st Qu.:  1.7600      1st Qu.: -88.30
## Median :424.0      Median :113.00      Median :  5.2800      Median : -13.00
## Mean    :430.6      Mean    : 64.41      Mean    :  0.3053      Mean    : -11.21
## 3rd Qu.:644.0      3rd Qu.:123.00      3rd Qu.:14.9000      3rd Qu.:  12.90
## Max.    :864.0      Max.    :162.00      Max.    : 60.3000      Max.    : 179.00
##
## total_accel_belt kurtosis_roll_belt kurtosis_pitch_belt
## Min.   : 0.00      Length:19622      Length:19622
## 1st Qu.: 3.00      Class :character  Class :character
## Median :17.00      Mode  :character  Mode  :character
## Mean    :11.31
## 3rd Qu.:18.00
## Max.    :29.00
##
## kurtosis_yaw_belt skewness_roll_belt skewness_roll_belt.1
## Length:19622      Length:19622      Length:19622
## Class :character  Class :character  Class :character
## Mode  :character  Mode  :character  Mode  :character
##
##
##
##
## skewness_yaw_belt max_roll_belt      max_pitch_belt max_yaw_belt
## Length:19622      Min.   : -94.300      Min.   :  3.00      Length:19622
## Class :character  1st Qu.: -88.000      1st Qu.:  5.00      Class :character
## Mode  :character  Median :  -5.100      Median :18.00      Mode  :character
##                      Mean    : -6.667      Mean    :12.92
##                      3rd Qu.: 18.500      3rd Qu.:19.00
##                      Max.    :180.000      Max.    :30.00
##                      NA's    :19216      NA's    :19216
## min_roll_belt      min_pitch_belt min_yaw_belt      amplitude_roll_belt
## Min.   : -180.00      Min.   :  0.00      Length:19622      Min.   :  0.000
## 1st Qu.: -88.40      1st Qu.:  3.00      Class :character  1st Qu.:  0.300
## Median :  -7.85      Median :16.00      Mode  :character  Median :  1.000
## Mean    : -10.44      Mean    :10.76                      Mean    :  3.769
## 3rd Qu.:  9.05      3rd Qu.:17.00                      3rd Qu.:  2.083
## Max.    : 173.00      Max.    :23.00                      Max.    :360.000
## NA's    :19216      NA's    :19216                      NA's    :19216
## amplitude_pitch_belt amplitude_yaw_belt var_total_accel_belt
## Min.   : 0.000      Length:19622      Min.   :  0.000
## 1st Qu.: 1.000      Class :character  1st Qu.:  0.100
## Median : 1.000      Mode  :character  Median :  0.200
## Mean    : 2.167                      Mean    :  0.926
## 3rd Qu.: 2.000                      3rd Qu.:  0.300
## Max.    :12.000                      Max.    :16.500
## NA's    :19216                      NA's    :19216

```

```

## avg_roll_belt      stddev_roll_belt var_roll_belt      avg_pitch_belt
## Min.      :-27.40   Min.      : 0.000   Min.      : 0.000   Min.      :-51.400
## 1st Qu.:   1.10   1st Qu.: 0.200   1st Qu.: 0.000   1st Qu.:  2.025
## Median : 116.35   Median : 0.400   Median : 0.100   Median :  5.200
## Mean      : 68.06   Mean      : 1.337   Mean      : 7.699   Mean      :  0.520
## 3rd Qu.: 123.38   3rd Qu.: 0.700   3rd Qu.: 0.500   3rd Qu.: 15.775
## Max.      :157.40   Max.      :14.200   Max.      :200.700   Max.      : 59.700
## NA's      :19216   NA's      :19216   NA's      :19216   NA's      :19216
## stddev_pitch_belt var_pitch_belt      avg_yaw_belt      stddev_yaw_belt
## Min.      :0.000   Min.      : 0.000   Min.      :-138.300   Min.      : 0.000
## 1st Qu.:0.200   1st Qu.: 0.000   1st Qu.: -88.175   1st Qu.:  0.100
## Median :0.400   Median : 0.100   Median : -6.550   Median :  0.300
## Mean      :0.603   Mean      : 0.766   Mean      : -8.831   Mean      :  1.341
## 3rd Qu.:0.700   3rd Qu.: 0.500   3rd Qu.: 14.125   3rd Qu.:  0.700
## Max.      :4.000   Max.      :16.200   Max.      : 173.500   Max.      :176.600
## NA's      :19216   NA's      :19216   NA's      :19216   NA's      :19216
## var_yaw_belt      gyros_belt_x      gyros_belt_y
## Min.      : 0.000   Min.      :-1.040000   Min.      :-0.64000
## 1st Qu.: 0.010   1st Qu.: -0.030000   1st Qu.: 0.00000
## Median : 0.090   Median : 0.030000   Median : 0.02000
## Mean      : 107.487   Mean      :-0.005592   Mean      : 0.03959
## 3rd Qu.: 0.475   3rd Qu.: 0.110000   3rd Qu.: 0.11000
## Max.      :31183.240   Max.      : 2.220000   Max.      : 0.64000
## NA's      :19216
## gyros_belt_z      accel_belt_x      accel_belt_y      accel_belt_z
## Min.      :-1.4600   Min.      :-120.000   Min.      :-69.00   Min.      :-275.00
## 1st Qu.: -0.2000   1st Qu.: -21.000   1st Qu.:  3.00   1st Qu.: -162.00
## Median : -0.1000   Median : -15.000   Median : 35.00   Median : -152.00
## Mean      : -0.1305   Mean      : -5.595   Mean      : 30.15   Mean      : -72.59
## 3rd Qu.: -0.0200   3rd Qu.: -5.000   3rd Qu.: 61.00   3rd Qu.:  27.00
## Max.      : 1.6200   Max.      : 85.000   Max.      :164.00   Max.      : 105.00
##
## magnet_belt_x      magnet_belt_y      magnet_belt_z      roll_arm
## Min.      :-52.0   Min.      :354.0   Min.      :-623.0   Min.      :-180.00
## 1st Qu.:  9.0   1st Qu.:581.0   1st Qu.: -375.0   1st Qu.: -31.77
## Median : 35.0   Median :601.0   Median : -320.0   Median :  0.00
## Mean      : 55.6   Mean      :593.7   Mean      : -345.5   Mean      : 17.83
## 3rd Qu.: 59.0   3rd Qu.:610.0   3rd Qu.: -306.0   3rd Qu.: 77.30
## Max.      :485.0   Max.      :673.0   Max.      : 293.0   Max.      : 180.00
##
## pitch_arm      yaw_arm      total_accel_arm var_accel_arm
## Min.      :-88.800   Min.      :-180.0000   Min.      : 1.00   Min.      : 0.00
## 1st Qu.: -25.900   1st Qu.: -43.1000   1st Qu.:17.00   1st Qu.:  9.03
## Median :  0.000   Median :  0.0000   Median :27.00   Median : 40.61
## Mean      : -4.612   Mean      : -0.6188   Mean      :25.51   Mean      : 53.23
## 3rd Qu.: 11.200   3rd Qu.: 45.8750   3rd Qu.:33.00   3rd Qu.: 75.62
## Max.      : 88.500   Max.      : 180.0000   Max.      :66.00   Max.      :331.70
## NA's      :19216
## avg_roll_arm      stddev_roll_arm      var_roll_arm      avg_pitch_arm
## Min.      :-166.67   Min.      : 0.000   Min.      : 0.000   Min.      :-81.773
## 1st Qu.: -38.37   1st Qu.: 1.376   1st Qu.: 1.898   1st Qu.: -22.770
## Median :  0.00   Median : 5.702   Median : 32.517   Median :  0.000
## Mean      : 12.68   Mean      : 11.201   Mean      : 417.264   Mean      : -4.901
## 3rd Qu.: 76.33   3rd Qu.: 14.921   3rd Qu.: 222.647   3rd Qu.:  8.277

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## Max. : 163.33 Max. :161.964 Max. :26232.208 Max. : 75.659
## NA's :19216 NA's :19216 NA's :19216 NA's :19216
## stddev_pitch_arm var_pitch_arm avg_yaw_arm stddev_yaw_arm
## Min. : 0.000 Min. : 0.000 Min. : -173.440 Min. : 0.000
## 1st Qu.: 1.642 1st Qu.: 2.697 1st Qu.: -29.198 1st Qu.: 2.577
## Median : 8.133 Median : 66.146 Median : 0.000 Median : 16.682
## Mean :10.383 Mean : 195.864 Mean : 2.359 Mean : 22.270
## 3rd Qu.:16.327 3rd Qu.: 266.576 3rd Qu.: 38.185 3rd Qu.: 35.984
## Max. :43.412 Max. :1884.565 Max. : 152.000 Max. :177.044
## NA's :19216 NA's :19216 NA's :19216 NA's :19216
## var_yaw_arm gyros_arm_x gyros_arm_y
## Min. : 0.000 Min. : -6.37000 Min. : -3.4400
## 1st Qu.: 6.642 1st Qu.: -1.33000 1st Qu.: -0.8000
## Median : 278.309 Median : 0.08000 Median : -0.2400
## Mean : 1055.933 Mean : 0.04277 Mean : -0.2571
## 3rd Qu.: 1294.850 3rd Qu.: 1.57000 3rd Qu.: 0.1400
## Max. :31344.568 Max. : 4.87000 Max. : 2.8400
## NA's :19216
## gyros_arm_z accel_arm_x accel_arm_y accel_arm_z
## Min. : -2.3300 Min. : -404.00 Min. : -318.0 Min. : -636.00
## 1st Qu.: -0.0700 1st Qu.: -242.00 1st Qu.: -54.0 1st Qu.: -143.00
## Median : 0.2300 Median : -44.00 Median : 14.0 Median : -47.00
## Mean : 0.2695 Mean : -60.24 Mean : 32.6 Mean : -71.25
## 3rd Qu.: 0.7200 3rd Qu.: 84.00 3rd Qu.: 139.0 3rd Qu.: 23.00
## Max. : 3.0200 Max. : 437.00 Max. : 308.0 Max. : 292.00
##
## magnet_arm_x magnet_arm_y magnet_arm_z kurtosis_roll_arm
## Min. : -584.0 Min. : -392.0 Min. : -597.0 Length:19622
## 1st Qu.: -300.0 1st Qu.: -9.0 1st Qu.: 131.2 Class :character
## Median : 289.0 Median : 202.0 Median : 444.0 Mode :character
## Mean : 191.7 Mean : 156.6 Mean : 306.5
## 3rd Qu.: 637.0 3rd Qu.: 323.0 3rd Qu.: 545.0
## Max. : 782.0 Max. : 583.0 Max. : 694.0
##
## kurtosis_pitch_arm kurtosis_yaw_arm skewness_roll_arm
## Length:19622 Length:19622 Length:19622
## Class :character Class :character Class :character
## Mode :character Mode :character Mode :character
##
##
##
## skewness_pitch_arm skewness_yaw_arm max_roll_arm
## Length:19622 Length:19622 Min. : -73.100
## Class :character Class :character 1st Qu.: -0.175
## Mode :character Mode :character Median : 4.950
## Mean : 11.236
## 3rd Qu.: 26.775
## Max. : 85.500
## NA's :19216
## max_pitch_arm max_yaw_arm min_roll_arm min_pitch_arm
## Min. : -173.000 Min. : 4.00 Min. : -89.10 Min. : -180.00
## 1st Qu.: -1.975 1st Qu.:29.00 1st Qu.: -41.98 1st Qu.: -72.62
## Median : 23.250 Median :34.00 Median : -22.45 Median : -33.85

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## Mean : 35.751 Mean :35.46 Mean :-21.22 Mean : -33.92
## 3rd Qu.: 95.975 3rd Qu.:41.00 3rd Qu.: 0.00 3rd Qu.: 0.00
## Max. : 180.000 Max. :65.00 Max. : 66.40 Max. : 152.00
## NA's :19216 NA's :19216 NA's :19216 NA's :19216
## min_yaw_arm amplitude_roll_arm amplitude_pitch_arm amplitude_yaw_arm
## Min. : 1.00 Min. : 0.000 Min. : 0.000 Min. : 0.00
## 1st Qu.: 8.00 1st Qu.: 5.425 1st Qu.: 9.925 1st Qu.:13.00
## Median :13.00 Median : 28.450 Median : 54.900 Median :22.00
## Mean :14.66 Mean : 32.452 Mean : 69.677 Mean :20.79
## 3rd Qu.:19.00 3rd Qu.: 50.960 3rd Qu.:115.175 3rd Qu.:28.75
## Max. :38.00 Max. :119.500 Max. :360.000 Max. :52.00
## NA's :19216 NA's :19216 NA's :19216 NA's :19216
## roll_dumbbell pitch_dumbbell yaw_dumbbell
## Min. : -153.71 Min. : -149.59 Min. : -150.871
## 1st Qu.: -18.49 1st Qu.: -40.89 1st Qu.: -77.644
## Median : 48.17 Median : -20.96 Median : -3.324
## Mean : 23.84 Mean : -10.78 Mean : 1.674
## 3rd Qu.: 67.61 3rd Qu.: 17.50 3rd Qu.: 79.643
## Max. : 153.55 Max. : 149.40 Max. : 154.952
##
## kurtosis_roll_dumbbell kurtosis_pitch_dumbbell kurtosis_yaw_dumbbell
## Length:19622 Length:19622 Length:19622
## Class :character Class :character Class :character
## Mode :character Mode :character Mode :character
##
##
##
## skewness_roll_dumbbell skewness_pitch_dumbbell skewness_yaw_dumbbell
## Length:19622 Length:19622 Length:19622
## Class :character Class :character Class :character
## Mode :character Mode :character Mode :character
##
##
##
## max_roll_dumbbell max_pitch_dumbbell max_yaw_dumbbell min_roll_dumbbell
## Min. : -70.10 Min. : -112.90 Length:19622 Min. : -149.60
## 1st Qu.: -27.15 1st Qu.: -66.70 Class :character 1st Qu.: -59.67
## Median : 14.85 Median : 40.05 Mode :character Median : -43.55
## Mean : 13.76 Mean : 32.75 Mean : -41.24
## 3rd Qu.: 50.58 3rd Qu.: 133.22 3rd Qu.: -25.20
## Max. :137.00 Max. : 155.00 Max. : 73.20
## NA's :19216 NA's :19216 NA's :19216
## min_pitch_dumbbell min_yaw_dumbbell amplitude_roll_dumbbell
## Min. : -147.00 Length:19622 Min. : 0.00
## 1st Qu.: -91.80 Class :character 1st Qu.: 14.97
## Median : -66.15 Mode :character Median : 35.05
## Mean : -33.18 Mean : 55.00
## 3rd Qu.: 21.20 3rd Qu.: 81.04
## Max. : 120.90 Max. :256.48
## NA's :19216 NA's :19216
## amplitude_pitch_dumbbell amplitude_yaw_dumbbell total_accel_dumbbell
## Min. : 0.00 Length:19622 Min. : 0.00

```

```

## 1st Qu.: 17.06          Class :character          1st Qu.: 4.00
## Median : 41.73          Mode  :character          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
##

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```

## pitch_forearm      yaw_forearm      kurtosis_roll_forearm
## Min.      :-72.50   Min.      :-180.00   Length:19622
## 1st Qu.:   0.00   1st Qu.:  -68.60   Class :character
## Median :   9.24   Median :    0.00   Mode  :character
## Mean  :  10.71   Mean   :   19.21
## 3rd Qu.:  28.40   3rd Qu.: 110.00
## Max.   :  89.80   Max.    : 180.00
##
## kurtosis_picth_forearm kurtosis_yaw_forearm skewness_roll_forearm
## Length:19622          Length:19622          Length:19622
## Class :character      Class :character      Class :character
## Mode  :character      Mode  :character      Mode  :character
##
##
##
## skewness_pitch_forearm skewness_yaw_forearm max_roll_forearm
## Length:19622          Length:19622          Min.      :-66.60
## Class :character      Class :character      1st Qu.:   0.00
## Mode  :character      Mode  :character      Median :  26.80
##                                     Mean  :  24.49
##                                     3rd Qu.:  45.95
##                                     Max.   :  89.80
##                                     NA's    :19216
## max_picth_forearm max_yaw_forearm      min_roll_forearm min_pitch_forearm
## Min.      :-151.00   Length:19622      Min.      :-72.500   Min.      :-180.00
## 1st Qu.:   0.00   Class :character  1st Qu.:  -6.075   1st Qu.: -175.00
## Median : 113.00   Mode  :character  Median :   0.000   Median :  -61.00
## Mean   :   81.49                                     Mean  :  -0.167   Mean   : -57.57
## 3rd Qu.: 174.75                                     3rd Qu.: 12.075   3rd Qu.:   0.00
## Max.    : 180.00                                     Max.    : 62.100   Max.    : 167.00
## NA's     :19216                                     NA's     :19216   NA's     :19216
## min_yaw_forearm      amplitude_roll_forearm amplitude_pitch_forearm
## Length:19622          Min.      :   0.000   Min.      :   0.0
## Class :character      1st Qu.:   1.125   1st Qu.:   2.0
## Mode  :character      Median : 17.770   Median :  83.7
##                                     Mean   : 24.653   Mean   :139.1
##                                     3rd Qu.: 39.875   3rd Qu.:350.0
##                                     Max.    :126.000   Max.    :360.0
##                                     NA's     :19216   NA's     :19216
## amplitude_yaw_forearm total_accel_forearm var_accel_forearm
## Length:19622          Min.      :   0.00   Min.      :   0.000
## Class :character      1st Qu.: 29.00   1st Qu.:   6.759
## Mode  :character      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

```

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## 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
## Length:19622
## Class :character
## Mode :character
##
##
##

```

```
summary(testing)
```

```

##      X      user_name      raw_timestamp_part_1
## Min. : 1.00 Length:20 Min. :1.322e+09
## 1st Qu.: 5.75 Class :character 1st Qu.:1.323e+09
## Median :10.50 Mode :character Median :1.323e+09
## Mean :10.50 Mean :1.323e+09
## 3rd Qu.:15.25 3rd Qu.:1.323e+09
## Max. :20.00 Max. :1.323e+09
## raw_timestamp_part_2 cvtd_timestamp      new_window
## Min. : 36553 Length:20 Length:20
## 1st Qu.:268655 Class :character Class :character

```



```

## Median :530706      Mode :character      Mode :character
## Mean    :512167
## 3rd Qu.:787738
## Max.    :920315
## num_window      roll_belt      pitch_belt      yaw_belt
## Min.   : 48.0    Min.   : -5.9200    Min.   : -41.600    Min.   : -93.70
## 1st Qu.:250.0    1st Qu.:  0.9075    1st Qu.:  3.013     1st Qu.: -88.62
## Median :384.5    Median :  1.1100    Median :  4.655     Median : -87.85
## Mean   :379.6    Mean   : 31.3055    Mean   :  5.824     Mean   : -59.30
## 3rd Qu.:467.0    3rd Qu.: 32.5050    3rd Qu.:  6.135     3rd Qu.: -63.50
## Max.   :859.0    Max.   :129.0000    Max.   : 27.800     Max.   :162.00
## total_accel_belt kurtosis_roll_belt kurtosis_pitch_belt kurtosis_yaw_belt
## Min.   : 2.00    Mode:logical      Mode:logical      Mode:logical
## 1st Qu.: 3.00    NA's:20           NA's:20           NA's:20
## Median : 4.00
## Mean   : 7.55
## 3rd Qu.: 8.00
## Max.   :21.00
## skewness_roll_belt skewness_roll_belt.1 skewness_yaw_belt max_roll_belt
## Mode:logical      Mode:logical      Mode:logical      Mode:logical
## NA's:20           NA's:20           NA's:20           NA's:20
##
##
##
## max_pitch_belt max_yaw_belt min_roll_belt min_pitch_belt
## Mode:logical   Mode:logical   Mode:logical   Mode:logical
## NA's:20        NA's:20        NA's:20        NA's:20
##
##
##
## min_yaw_belt amplitude_roll_belt amplitude_pitch_belt
## Mode:logical   Mode:logical   Mode:logical
## NA's:20        NA's:20        NA's:20
##
##
##
## amplitude_yaw_belt var_total_accel_belt avg_roll_belt stddev_roll_belt
## Mode:logical      Mode:logical      Mode:logical      Mode:logical
## NA's:20           NA's:20           NA's:20           NA's:20
##
##
##
## var_roll_belt avg_pitch_belt stddev_pitch_belt var_pitch_belt
## Mode:logical   Mode:logical   Mode:logical      Mode:logical
## NA's:20        NA's:20        NA's:20           NA's:20
##
##
##
## avg_yaw_belt stddev_yaw_belt var_yaw_belt gyros_belt_x

```

```

## Mode:logical Mode:logical Mode:logical Min. :-0.500
## NA's:20 NA's:20 NA's:20 1st Qu.: -0.070
## Median : 0.020
## Mean :-0.045
## 3rd Qu.: 0.070
## Max. : 0.240
## gyros_belt_y gyros_belt_z accel_belt_x accel_belt_y
## Min. :-0.050 Min. :-0.4800 Min. :-48.00 Min. :-16.00
## 1st Qu.: -0.005 1st Qu.: -0.1375 1st Qu.: -19.00 1st Qu.: 2.00
## Median : 0.000 Median :-0.0250 Median :-13.00 Median : 4.50
## Mean : 0.010 Mean :-0.1005 Mean :-13.50 Mean : 18.35
## 3rd Qu.: 0.020 3rd Qu.: 0.0000 3rd Qu.: -8.75 3rd Qu.: 25.50
## Max. : 0.110 Max. : 0.0500 Max. : 46.00 Max. : 72.00
## accel_belt_z magnet_belt_x magnet_belt_y magnet_belt_z
## Min. :-187.00 Min. :-13.00 Min. :566.0 Min. :-426.0
## 1st Qu.: -24.00 1st Qu.: 5.50 1st Qu.:578.5 1st Qu.: -398.5
## Median : 27.00 Median : 33.50 Median :600.5 Median :-313.5
## Mean : -17.60 Mean : 35.15 Mean :601.5 Mean :-346.9
## 3rd Qu.: 38.25 3rd Qu.: 46.25 3rd Qu.:631.2 3rd Qu.: -305.0
## Max. : 49.00 Max. :169.00 Max. :638.0 Max. :-291.0
## roll_arm pitch_arm yaw_arm total_accel_arm
## Min. :-137.00 Min. :-63.800 Min. :-167.00 Min. : 3.00
## 1st Qu.: 0.00 1st Qu.: -9.188 1st Qu.: -60.15 1st Qu.:20.25
## Median : 0.00 Median : 0.000 Median : 0.00 Median :29.50
## Mean : 16.42 Mean : -3.950 Mean : -2.80 Mean :26.40
## 3rd Qu.: 71.53 3rd Qu.: 3.465 3rd Qu.: 25.50 3rd Qu.:33.25
## Max. : 152.00 Max. : 55.000 Max. : 178.00 Max. :44.00
## var_accel_arm avg_roll_arm stddev_roll_arm var_roll_arm
## Mode:logical Mode:logical Mode:logical Mode:logical
## NA's:20 NA's:20 NA's:20 NA's:20
##
##
##
## avg_pitch_arm stddev_pitch_arm var_pitch_arm avg_yaw_arm
## Mode:logical Mode:logical Mode:logical Mode:logical
## NA's:20 NA's:20 NA's:20 NA's:20
##
##
##
## stddev_yaw_arm var_yaw_arm gyros_arm_x gyros_arm_y
## Mode:logical Mode:logical Min. :-3.710 Min. :-2.0900
## NA's:20 NA's:20 1st Qu.: -0.645 1st Qu.: -0.6350
## Median : 0.020 Median :-0.0400
## Mean : 0.077 Mean :-0.1595
## 3rd Qu.: 1.248 3rd Qu.: 0.2175
## Max. : 3.660 Max. : 1.8500
## gyros_arm_z accel_arm_x accel_arm_y accel_arm_z
## Min. :-0.6900 Min. :-341.0 Min. :-65.00 Min. :-404.00
## 1st Qu.: -0.1800 1st Qu.: -277.0 1st Qu.: 52.25 1st Qu.: -128.50
## Median :-0.0250 Median :-194.5 Median :112.00 Median : -83.50
## Mean : 0.1205 Mean :-134.6 Mean :103.10 Mean : -87.85
## 3rd Qu.: 0.5650 3rd Qu.: 5.5 3rd Qu.:168.25 3rd Qu.: -27.25

```

```

## Max. : 1.1300 Max. : 106.0 Max. :245.00 Max. : 93.00
## magnet_arm_x magnet_arm_y magnet_arm_z kurtosis_roll_arm
## Min. : -428.00 Min. : -307.0 Min. : -499.0 Mode:logical
## 1st Qu.: -373.75 1st Qu.: 205.2 1st Qu.: 403.0 NA's:20
## Median : -265.00 Median : 291.0 Median : 476.5
## Mean : -38.95 Mean : 239.4 Mean : 369.8
## 3rd Qu.: 250.50 3rd Qu.: 358.8 3rd Qu.: 517.0
## Max. : 750.00 Max. : 474.0 Max. : 633.0
## kurtosis_picth_arm kurtosis_yaw_arm skewness_roll_arm skewness_pitch_arm
## Mode:logical Mode:logical Mode:logical Mode:logical
## NA's:20 NA's:20 NA's:20 NA's:20
##
##
##
## skewness_yaw_arm max_roll_arm max_picth_arm max_yaw_arm
## Mode:logical Mode:logical Mode:logical Mode:logical
## NA's:20 NA's:20 NA's:20 NA's:20
##
##
##
## min_roll_arm min_pitch_arm min_yaw_arm amplitude_roll_arm
## Mode:logical Mode:logical Mode:logical Mode:logical
## NA's:20 NA's:20 NA's:20 NA's:20
##
##
##
## amplitude_pitch_arm amplitude_yaw_arm roll_dumbbell pitch_dumbbell
## Mode:logical Mode:logical Min. : -111.118 Min. : -54.97
## NA's:20 NA's:20 1st Qu.: 7.494 1st Qu.: -51.89
## Median : 50.403 Median : -40.81
## Mean : 33.760 Mean : -19.47
## 3rd Qu.: 58.129 3rd Qu.: 16.12
## Max. : 123.984 Max. : 96.87
## yaw_dumbbell kurtosis_roll_dumbbell kurtosis_picth_dumbbell
## Min. : -103.3200 Mode:logical Mode:logical
## 1st Qu.: -75.2809 NA's:20 NA's:20
## Median : -8.2863
## Mean : -0.9385
## 3rd Qu.: 55.8335
## Max. : 132.2337
## kurtosis_yaw_dumbbell skewness_roll_dumbbell skewness_pitch_dumbbell
## Mode:logical Mode:logical Mode:logical
## NA's:20 NA's:20 NA's:20
##
##
##
## skewness_yaw_dumbbell max_roll_dumbbell max_picth_dumbbell
## Mode:logical Mode:logical Mode:logical
## NA's:20 NA's:20 NA's:20
##

```

```

##
##
##
## max_yaw_dumbbell min_roll_dumbbell min_pitch_dumbbell min_yaw_dumbbell
## Mode:logical      Mode:logical      Mode:logical      Mode:logical
## NA's:20           NA's:20           NA's:20           NA's:20
##
##
##
##
## amplitude_roll_dumbbell amplitude_pitch_dumbbell amplitude_yaw_dumbbell
## Mode:logical      Mode:logical      Mode:logical
## NA's:20           NA's:20           NA's:20
##
##
##
## total_accel_dumbbell var_accel_dumbbell avg_roll_dumbbell
## Min. : 1.0           Mode:logical      Mode:logical
## 1st Qu.: 7.0         NA's:20           NA's:20
## Median :15.5
## Mean :17.2
## 3rd Qu.:29.0
## Max. :31.0
## stddev_roll_dumbbell var_roll_dumbbell avg_pitch_dumbbell
## Mode:logical      Mode:logical      Mode:logical
## NA's:20           NA's:20           NA's:20
##
##
##
## stddev_pitch_dumbbell var_pitch_dumbbell avg_yaw_dumbbell
## Mode:logical      Mode:logical      Mode:logical
## NA's:20           NA's:20           NA's:20
##
##
##
##
## stddev_yaw_dumbbell var_yaw_dumbbell gyros_dumbbell_x gyros_dumbbell_y
## Mode:logical      Mode:logical      Min. : -1.0300 Min. : -1.1100
## NA's:20           NA's:20           1st Qu.: 0.1600 1st Qu.: -0.2100
## Median : 0.3600 Median : 0.0150
## Mean : 0.2690 Mean : 0.0605
## 3rd Qu.: 0.4625 3rd Qu.: 0.1450
## Max. : 1.0600 Max. : 1.9100
## gyros_dumbbell_z accel_dumbbell_x accel_dumbbell_y accel_dumbbell_z
## Min. : -1.180 Min. : -159.00 Min. : -30.00 Min. : -221.0
## 1st Qu.: -0.485 1st Qu.: -140.25 1st Qu.: 5.75 1st Qu.: -192.2
## Median : -0.280 Median : -19.00 Median : 71.50 Median : -3.0
## Mean : -0.266 Mean : -47.60 Mean : 70.55 Mean : -60.0
## 3rd Qu.: -0.165 3rd Qu.: 15.75 3rd Qu.: 151.25 3rd Qu.: 76.5
## Max. : 1.100 Max. : 185.00 Max. : 166.00 Max. : 100.0
## magnet_dumbbell_x magnet_dumbbell_y magnet_dumbbell_z roll_forearm
## Min. : -576.0 Min. : -558.0 Min. : -164.00 Min. : -176.00

```

```

## 1st Qu.: -528.0    1st Qu.: 259.5    1st Qu.: -33.00    1st Qu.: -40.25
## Median : -508.5    Median : 316.0    Median : 49.50    Median : 94.20
## Mean   : -304.2    Mean   : 189.3    Mean   : 71.40    Mean   : 38.66
## 3rd Qu.: -317.0    3rd Qu.: 348.2    3rd Qu.: 96.25    3rd Qu.: 143.25
## Max.    : 523.0    Max.    : 403.0    Max.    : 368.00    Max.    : 176.00
## pitch_forearm      yaw_forearm      kurtosis_roll_forearm
## Min.      : -63.500    Min.      : -168.000    Mode:logical
## 1st Qu.: -11.457    1st Qu.: -93.375    NA's:20
## Median : 8.830    Median : -19.250
## Mean   : 7.099    Mean   : 2.195
## 3rd Qu.: 28.500    3rd Qu.: 104.500
## Max.    : 59.300    Max.    : 159.000
## kurtosis_picth_forearm kurtosis_yaw_forearm skewness_roll_forearm
## Mode:logical      Mode:logical      Mode:logical
## NA's:20            NA's:20            NA's:20
##
##
##
## skewness_pitch_forearm skewness_yaw_forearm max_roll_forearm
## Mode:logical      Mode:logical      Mode:logical
## NA's:20            NA's:20            NA's:20
##
##
##
## max_picth_forearm max_yaw_forearm min_roll_forearm min_pitch_forearm
## Mode:logical      Mode:logical      Mode:logical      Mode:logical
## NA's:20            NA's:20            NA's:20            NA's:20
##
##
##
## min_yaw_forearm amplitude_roll_forearm amplitude_pitch_forearm
## Mode:logical      Mode:logical      Mode:logical
## NA's:20            NA's:20            NA's:20
##
##
##
## amplitude_yaw_forearm total_accel_forearm var_accel_forearm
## Mode:logical      Min.      :21.00      Mode:logical
## NA's:20            1st Qu.:24.00      NA's:20
##                    Median :32.50
##                    Mean   :32.05
##                    3rd Qu.:36.75
##                    Max.    :47.00
## avg_roll_forearm stddev_roll_forearm var_roll_forearm avg_pitch_forearm
## Mode:logical      Mode:logical      Mode:logical      Mode:logical
## NA's:20            NA's:20            NA's:20            NA's:20
##
##
##
##

```

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

Data Validation

Following is the information re. the percentage of column being NA. If the percentage NA > 0, it will be removed in the following block

```
round(colSums(is.na(training))/nrow(training), 4)
```

```
##          X          user_name raw_timestamp_part_1
##      0.0000          0.0000          0.0000
## raw_timestamp_part_2 cvtd_timestamp new_window
##      0.0000          0.0000          0.0000
##      num_window      roll_belt pitch_belt
##      0.0000          0.0000          0.0000
##      yaw_belt      total_accel_belt kurtosis_roll_belt
##      0.0000          0.0000          0.9793
##      kurtosis_pitch_belt kurtosis_yaw_belt skewness_roll_belt
##      0.9793          0.9793          0.9793
##      skewness_roll_belt.1 skewness_yaw_belt max_roll_belt
##      0.9793          0.9793          0.9793
##      max_pitch_belt      max_yaw_belt min_roll_belt
##      0.9793          0.9793          0.9793
##      min_pitch_belt      min_yaw_belt amplitude_roll_belt
##      0.9793          0.9793          0.9793
##      amplitude_pitch_belt amplitude_yaw_belt var_total_accel_belt
##      0.9793          0.9793          0.9793
```

##	avg_roll_belt	stddev_roll_belt	var_roll_belt
##	0.9793	0.9793	0.9793
##	avg_pitch_belt	stddev_pitch_belt	var_pitch_belt
##	0.9793	0.9793	0.9793
##	avg_yaw_belt	stddev_yaw_belt	var_yaw_belt
##	0.9793	0.9793	0.9793
##	gyros_belt_x	gyros_belt_y	gyros_belt_z
##	0.0000	0.0000	0.0000
##	accel_belt_x	accel_belt_y	accel_belt_z
##	0.0000	0.0000	0.0000
##	magnet_belt_x	magnet_belt_y	magnet_belt_z
##	0.0000	0.0000	0.0000
##	roll_arm	pitch_arm	yaw_arm
##	0.0000	0.0000	0.0000
##	total_accel_arm	var_accel_arm	avg_roll_arm
##	0.0000	0.9793	0.9793
##	stddev_roll_arm	var_roll_arm	avg_pitch_arm
##	0.9793	0.9793	0.9793
##	stddev_pitch_arm	var_pitch_arm	avg_yaw_arm
##	0.9793	0.9793	0.9793
##	stddev_yaw_arm	var_yaw_arm	gyros_arm_x
##	0.9793	0.9793	0.0000
##	gyros_arm_y	gyros_arm_z	accel_arm_x
##	0.0000	0.0000	0.0000
##	accel_arm_y	accel_arm_z	magnet_arm_x
##	0.0000	0.0000	0.0000
##	magnet_arm_y	magnet_arm_z	kurtosis_roll_arm
##	0.0000	0.0000	0.9793
##	kurtosis_pitch_arm	kurtosis_yaw_arm	skewness_roll_arm
##	0.9793	0.9793	0.9793
##	skewness_pitch_arm	skewness_yaw_arm	max_roll_arm
##	0.9793	0.9793	0.9793
##	max_pitch_arm	max_yaw_arm	min_roll_arm
##	0.9793	0.9793	0.9793
##	min_pitch_arm	min_yaw_arm	amplitude_roll_arm
##	0.9793	0.9793	0.9793
##	amplitude_pitch_arm	amplitude_yaw_arm	roll_dumbbell
##	0.9793	0.9793	0.0000
##	pitch_dumbbell	yaw_dumbbell	kurtosis_roll_dumbbell
##	0.0000	0.0000	0.9793
##	kurtosis_pitch_dumbbell	kurtosis_yaw_dumbbell	skewness_roll_dumbbell
##	0.9793	0.9793	0.9793
##	skewness_pitch_dumbbell	skewness_yaw_dumbbell	max_roll_dumbbell
##	0.9793	0.9793	0.9793
##	max_pitch_dumbbell	max_yaw_dumbbell	min_roll_dumbbell
##	0.9793	0.9793	0.9793
##	min_pitch_dumbbell	min_yaw_dumbbell	amplitude_roll_dumbbell
##	0.9793	0.9793	0.9793
##	amplitude_pitch_dumbbell	amplitude_yaw_dumbbell	total_accel_dumbbell
##	0.9793	0.9793	0.0000
##	var_accel_dumbbell	avg_roll_dumbbell	stddev_roll_dumbbell
##	0.9793	0.9793	0.9793
##	var_roll_dumbbell	avg_pitch_dumbbell	stddev_pitch_dumbbell
##	0.9793	0.9793	0.9793

```
##      var_pitch_dumbbell      avg_yaw_dumbbell      stddev_yaw_dumbbell
##      0.9793      0.9793      0.9793
##      var_yaw_dumbbell      gyros_dumbbell_x      gyros_dumbbell_y
##      0.9793      0.0000      0.0000
##      gyros_dumbbell_z      accel_dumbbell_x      accel_dumbbell_y
##      0.0000      0.0000      0.0000
##      accel_dumbbell_z      magnet_dumbbell_x      magnet_dumbbell_y
##      0.0000      0.0000      0.0000
##      magnet_dumbbell_z      roll_forearm      pitch_forearm
##      0.0000      0.0000      0.0000
##      yaw_forearm      kurtosis_roll_forearm      kurtosis_pitch_forearm
##      0.0000      0.9793      0.9793
##      kurtosis_yaw_forearm      skewness_roll_forearm      skewness_pitch_forearm
##      0.9793      0.9793      0.9793
##      skewness_yaw_forearm      max_roll_forearm      max_pitch_forearm
##      0.9793      0.9793      0.9793
##      max_yaw_forearm      min_roll_forearm      min_pitch_forearm
##      0.9793      0.9793      0.9793
##      min_yaw_forearm      amplitude_roll_forearm      amplitude_pitch_forearm
##      0.9793      0.9793      0.9793
##      amplitude_yaw_forearm      total_accel_forearm      var_accel_forearm
##      0.9793      0.0000      0.9793
##      avg_roll_forearm      stddev_roll_forearm      var_roll_forearm
##      0.9793      0.9793      0.9793
##      avg_pitch_forearm      stddev_pitch_forearm      var_pitch_forearm
##      0.9793      0.9793      0.9793
##      avg_yaw_forearm      stddev_yaw_forearm      var_yaw_forearm
##      0.9793      0.9793      0.9793
##      gyros_forearm_x      gyros_forearm_y      gyros_forearm_z
##      0.0000      0.0000      0.0000
##      accel_forearm_x      accel_forearm_y      accel_forearm_z
##      0.0000      0.0000      0.0000
##      magnet_forearm_x      magnet_forearm_y      magnet_forearm_z
##      0.0000      0.0000      0.0000
##      classe
##      0.0000
```

```
rem.columns <- names(which(colSums(is.na(training))>0))
subTrain <- training[, !(names(training) %in% rem.columns)]
subTest <- testing[, !(names(testing) %in% rem.columns)]
```

To avoid overfitting, next we will remove the variables whose values don't change much to avoid overfitting.

```
# remove columns with near zero value (since they have virtually
# no variability), using nzv since potentially can cause overfitting
subTrain <- subTrain[, names(subTrain)[!(nearZeroVar(subTrain, saveMetrics = T)[, 4])]]
```

After looking through the dataframe and the data dictionary, I will remove a few other columns because I have determined that they will not impact the final classification. However, someone with more domain knowledge may overrule me and choose to use them.

```
# remove first seven columns as they are useless for predicting
subTrain <- subTrain[, 8:length(colnames(subTrain))]
subTest <- subTest[, 8:length(colnames(subTest))]
```


Partition the train and test data

Next we will partition the data into test and training samples and set up the training and test variables for use by the caret package.

```
set.seed(12345)
inTrain <- createDataPartition(subTrain$classe, p = 0.60, list = FALSE)
subTraining <- subTrain[inTrain, ]
subValidation <- subTrain[-inTrain, ]

y <- subTraining$classe
x <- subTraining[, -52]
```

Fit model parameters

To avoid overweighting parameters that may cause issue with the modeling, I have chosen to preprocess that data by centering and scaling. Also, I have chosen to enable crossvalidation

```
model_rf <- train(x, y,
  preProcess = c("center", "scale"),
  trControl = trainControl(method = "cv", number = 4),
  method = "rf")
```

```
## Loading required package: randomForest
## Warning: package 'randomForest' was built under R version 3.3.3
## randomForest 4.6-12
## Type rfNews() to see new features/changes/bug fixes.
##
## Attaching package: 'randomForest'
## The following object is masked from 'package:ggplot2':
##
##     margin
predict_rf <- predict(model_rf, subValidation)
print(confusionMatrix(predict_rf, subValidation$classe), digits = 4)
```

```
## Confusion Matrix and Statistics
##
##           Reference
## Prediction  A    B    C    D    E
##      A 2230   11    0    0    0
##      B   2 1501    8    0    0
##      C   0    5 1357   18    2
##      D   0    0    3 1266    6
##      E   0    1    0    2 1434
##
## Overall Statistics
##
##               Accuracy : 0.9926
##               95% CI : (0.9905, 0.9944)
##      No Information Rate : 0.2845
##      P-Value [Acc > NIR] : < 2.2e-16
```

```

##
##           Kappa : 0.9906
## Mcnemar's Test P-Value : NA
##
## Statistics by Class:
##
##           Class: A Class: B Class: C Class: D Class: E
## Sensitivity      0.9991  0.9888  0.9920  0.9844  0.9945
## Specificity      0.9980  0.9984  0.9961  0.9986  0.9995
## Pos Pred Value   0.9951  0.9934  0.9819  0.9929  0.9979
## Neg Pred Value   0.9996  0.9973  0.9983  0.9970  0.9988
## Prevalence       0.2845  0.1935  0.1744  0.1639  0.1838
## Detection Rate   0.2842  0.1913  0.1730  0.1614  0.1828
## Detection Prevalence 0.2856  0.1926  0.1761  0.1625  0.1832
## Balanced Accuracy 0.9986  0.9936  0.9940  0.9915  0.9970

```

```

varImp(model_rf)

## rf variable importance
##
##   only 20 most important variables shown (out of 51)
##
##           Overall
## yaw_belt      100.00
## pitch_forearm  86.14
## pitch_belt     70.73
## magnet_dumbbell_z 64.03
## magnet_dumbbell_y 52.82
## roll_forearm   44.74
## accel_belt_z   41.49
## gyros_belt_z   28.67
## magnet_dumbbell_x 28.07
## accel_dumbbell_y 27.23
## magnet_belt_z  26.58
## magnet_belt_y  25.68
## roll_dumbbell  24.42
## accel_forearm_x 23.45
## accel_dumbbell_z 18.80
## magnet_belt_x  18.66
## total_accel_dumbbell 17.01
## magnet_forearm_z 15.85
## yaw_arm        14.61
## roll_arm       13.51

```

```

model_rpart <- train(x, y,
  preProcess = c("center", "scale"),
  trControl = trainControl(method = "cv", number = 4),
  method="rpart")

```

```

## Loading required package: rpart
predict_rpart <- predict(model_rpart, subValidation)
print(confusionMatrix(predict_rpart, subValidation$classe), digits = 4)

## Confusion Matrix and Statistics
##

```

```
##           Reference
## Prediction    A    B    C    D    E
##           A 1972  454   98  168  146
##           B   53  686   40   85  311
##           C  157  234 1061  649  355
##           D   46  143  155  384   4
##           E    4   1   14   0  626
##
## Overall Statistics
##
##           Accuracy : 0.6027
##           95% CI : (0.5918, 0.6136)
##           No Information Rate : 0.2845
##           P-Value [Acc > NIR] : < 2.2e-16
##
##           Kappa : 0.4927
##           McNemar's Test P-Value : < 2.2e-16
##
## Statistics by Class:
##
##           Class: A Class: B Class: C Class: D Class: E
## Sensitivity      0.8835  0.45191  0.7756  0.29860  0.43412
## Specificity      0.8457  0.92272  0.7847  0.94695  0.99703
## Pos Pred Value   0.6949  0.58383  0.4320  0.52459  0.97054
## Neg Pred Value   0.9481  0.87528  0.9430  0.87321  0.88668
## Prevalence       0.2845  0.19347  0.1744  0.16391  0.18379
## Detection Rate   0.2513  0.08743  0.1352  0.04894  0.07979
## Detection Prevalence 0.3617  0.14976  0.3130  0.09330  0.08221
## Balanced Accuracy 0.8646  0.68732  0.7801  0.62278  0.71558
```

```
varImp(model_rpart)
```

```
## rpart variable importance
##
##   only 20 most important variables shown (out of 51)
##
##           Overall
## magnet_dumbbell_y    100.00
## gyros_belt_z         92.01
## accel_belt_z         89.07
## magnet_belt_y        85.19
## yaw_belt             70.27
## roll_dumbbell        65.25
## total_accel_belt     62.52
## magnet_dumbbell_z    60.25
## accel_dumbbell_y     56.62
## pitch_forearm        46.20
## pitch_belt           45.66
## accel_dumbbell_x     42.82
## magnet_belt_z        37.97
## total_accel_dumbbell 25.82
## accel_forearm_x      24.05
## roll_forearm         16.89
## magnet_dumbbell_x    14.87
## yaw_arm              13.66
```

```
## gyros_belt_y          11.78
## gyros_dumbbell_z      0.00
model_gbm <- train(x, y,
  preProcess = c("center","scale"),
  trControl = trainControl(method = "cv", number = 4),
  method="gbm")
```

```
## Loading required package: gbm
## Warning: package 'gbm' was built under R version 3.3.3
## Loading required package: survival
##
## Attaching package: 'survival'
## The following object is masked from 'package:caret':
##
##   cluster
## Loading required package: splines
## Loading required package: parallel
## Loaded gbm 2.1.3
## Loading required package: plyr
```

## Iter	TrainDeviance	ValidDeviance	StepSize	Improve
## 1	1.6094	nan	0.1000	0.1162
## 2	1.5370	nan	0.1000	0.0765
## 3	1.4889	nan	0.1000	0.0607
## 4	1.4506	nan	0.1000	0.0507
## 5	1.4185	nan	0.1000	0.0446
## 6	1.3895	nan	0.1000	0.0391
## 7	1.3644	nan	0.1000	0.0305
## 8	1.3444	nan	0.1000	0.0344
## 9	1.3226	nan	0.1000	0.0329
## 10	1.3004	nan	0.1000	0.0264
## 20	1.1541	nan	0.1000	0.0155
## 40	0.9817	nan	0.1000	0.0100
## 60	0.8648	nan	0.1000	0.0061
## 80	0.7811	nan	0.1000	0.0040
## 100	0.7147	nan	0.1000	0.0046
## 120	0.6599	nan	0.1000	0.0028
## 140	0.6133	nan	0.1000	0.0014
## 150	0.5928	nan	0.1000	0.0024

## Iter	TrainDeviance	ValidDeviance	StepSize	Improve
## 1	1.6094	nan	0.1000	0.1719
## 2	1.5005	nan	0.1000	0.1148
## 3	1.4279	nan	0.1000	0.0895
## 4	1.3706	nan	0.1000	0.0764
## 5	1.3231	nan	0.1000	0.0672
## 6	1.2817	nan	0.1000	0.0627
## 7	1.2434	nan	0.1000	0.0624
## 8	1.2052	nan	0.1000	0.0559
## 9	1.1708	nan	0.1000	0.0425

##	10	1.1435	nan	0.1000	0.0370
##	20	0.9418	nan	0.1000	0.0226
##	40	0.7191	nan	0.1000	0.0118
##	60	0.5790	nan	0.1000	0.0057
##	80	0.4860	nan	0.1000	0.0042
##	100	0.4100	nan	0.1000	0.0020
##	120	0.3528	nan	0.1000	0.0021
##	140	0.3085	nan	0.1000	0.0026
##	150	0.2901	nan	0.1000	0.0021
##					
##	Iter	TrainDeviance	ValidDeviance	StepSize	Improve
##	1	1.6094	nan	0.1000	0.2167
##	2	1.4756	nan	0.1000	0.1527
##	3	1.3822	nan	0.1000	0.1145
##	4	1.3110	nan	0.1000	0.0993
##	5	1.2470	nan	0.1000	0.0858
##	6	1.1933	nan	0.1000	0.0676
##	7	1.1498	nan	0.1000	0.0712
##	8	1.1056	nan	0.1000	0.0591
##	9	1.0682	nan	0.1000	0.0511
##	10	1.0361	nan	0.1000	0.0490
##	20	0.8021	nan	0.1000	0.0277
##	40	0.5518	nan	0.1000	0.0105
##	60	0.4150	nan	0.1000	0.0059
##	80	0.3302	nan	0.1000	0.0039
##	100	0.2729	nan	0.1000	0.0036
##	120	0.2254	nan	0.1000	0.0015
##	140	0.1902	nan	0.1000	0.0015
##	150	0.1768	nan	0.1000	0.0010
##					
##	Iter	TrainDeviance	ValidDeviance	StepSize	Improve
##	1	1.6094	nan	0.1000	0.1168
##	2	1.5384	nan	0.1000	0.0788
##	3	1.4905	nan	0.1000	0.0576
##	4	1.4535	nan	0.1000	0.0463
##	5	1.4246	nan	0.1000	0.0498
##	6	1.3930	nan	0.1000	0.0380
##	7	1.3677	nan	0.1000	0.0385
##	8	1.3426	nan	0.1000	0.0318
##	9	1.3227	nan	0.1000	0.0313
##	10	1.3025	nan	0.1000	0.0226
##	20	1.1573	nan	0.1000	0.0178
##	40	0.9805	nan	0.1000	0.0093
##	60	0.8693	nan	0.1000	0.0061
##	80	0.7828	nan	0.1000	0.0056
##	100	0.7170	nan	0.1000	0.0028
##	120	0.6606	nan	0.1000	0.0031
##	140	0.6145	nan	0.1000	0.0026
##	150	0.5927	nan	0.1000	0.0024
##					
##	Iter	TrainDeviance	ValidDeviance	StepSize	Improve
##	1	1.6094	nan	0.1000	0.1705
##	2	1.5024	nan	0.1000	0.1158
##	3	1.4287	nan	0.1000	0.0964

##	4	1.3689	nan	0.1000	0.0801
##	5	1.3175	nan	0.1000	0.0651
##	6	1.2766	nan	0.1000	0.0604
##	7	1.2386	nan	0.1000	0.0515
##	8	1.2049	nan	0.1000	0.0538
##	9	1.1715	nan	0.1000	0.0524
##	10	1.1399	nan	0.1000	0.0375
##	20	0.9449	nan	0.1000	0.0266
##	40	0.7185	nan	0.1000	0.0107
##	60	0.5810	nan	0.1000	0.0057
##	80	0.4831	nan	0.1000	0.0050
##	100	0.4124	nan	0.1000	0.0040
##	120	0.3577	nan	0.1000	0.0032
##	140	0.3160	nan	0.1000	0.0027
##	150	0.2970	nan	0.1000	0.0024

##

##	Iter	TrainDeviance	ValidDeviance	StepSize	Improve
##	1	1.6094	nan	0.1000	0.2100
##	2	1.4775	nan	0.1000	0.1478
##	3	1.3850	nan	0.1000	0.1223
##	4	1.3099	nan	0.1000	0.0933
##	5	1.2502	nan	0.1000	0.0820
##	6	1.1981	nan	0.1000	0.0738
##	7	1.1516	nan	0.1000	0.0606
##	8	1.1129	nan	0.1000	0.0519
##	9	1.0787	nan	0.1000	0.0538
##	10	1.0449	nan	0.1000	0.0456
##	20	0.8058	nan	0.1000	0.0280
##	40	0.5588	nan	0.1000	0.0127
##	60	0.4209	nan	0.1000	0.0063
##	80	0.3369	nan	0.1000	0.0043
##	100	0.2769	nan	0.1000	0.0022
##	120	0.2354	nan	0.1000	0.0025
##	140	0.2004	nan	0.1000	0.0009
##	150	0.1866	nan	0.1000	0.0018

##

##	Iter	TrainDeviance	ValidDeviance	StepSize	Improve
##	1	1.6094	nan	0.1000	0.1132
##	2	1.5373	nan	0.1000	0.0759
##	3	1.4885	nan	0.1000	0.0616
##	4	1.4505	nan	0.1000	0.0502
##	5	1.4196	nan	0.1000	0.0446
##	6	1.3909	nan	0.1000	0.0398
##	7	1.3639	nan	0.1000	0.0351
##	8	1.3401	nan	0.1000	0.0346
##	9	1.3184	nan	0.1000	0.0282
##	10	1.2999	nan	0.1000	0.0333
##	20	1.1480	nan	0.1000	0.0150
##	40	0.9741	nan	0.1000	0.0103
##	60	0.8616	nan	0.1000	0.0080
##	80	0.7766	nan	0.1000	0.0058
##	100	0.7088	nan	0.1000	0.0042
##	120	0.6566	nan	0.1000	0.0034
##	140	0.6116	nan	0.1000	0.0034

```

##      150      0.5903      nan      0.1000      0.0024
##
## Iter   TrainDeviance   ValidDeviance   StepSize   Improve
##      1      1.6094      nan      0.1000      0.1766
##      2      1.5015      nan      0.1000      0.1162
##      3      1.4273      nan      0.1000      0.0970
##      4      1.3660      nan      0.1000      0.0781
##      5      1.3169      nan      0.1000      0.0663
##      6      1.2754      nan      0.1000      0.0660
##      7      1.2341      nan      0.1000      0.0576
##      8      1.1984      nan      0.1000      0.0493
##      9      1.1668      nan      0.1000      0.0410
##     10      1.1402      nan      0.1000      0.0441
##     20      0.9438      nan      0.1000      0.0258
##     40      0.7177      nan      0.1000      0.0172
##     60      0.5705      nan      0.1000      0.0088
##     80      0.4816      nan      0.1000      0.0068
##    100      0.4128      nan      0.1000      0.0057
##    120      0.3590      nan      0.1000      0.0050
##    140      0.3158      nan      0.1000      0.0032
##    150      0.2958      nan      0.1000      0.0017
##
## Iter   TrainDeviance   ValidDeviance   StepSize   Improve
##      1      1.6094      nan      0.1000      0.2192
##      2      1.4750      nan      0.1000      0.1505
##      3      1.3814      nan      0.1000      0.1123
##      4      1.3101      nan      0.1000      0.1050
##      5      1.2457      nan      0.1000      0.0891
##      6      1.1916      nan      0.1000      0.0698
##      7      1.1491      nan      0.1000      0.0615
##      8      1.1092      nan      0.1000      0.0666
##      9      1.0687      nan      0.1000      0.0576
##     10      1.0334      nan      0.1000      0.0493
##     20      0.8008      nan      0.1000      0.0246
##     40      0.5555      nan      0.1000      0.0123
##     60      0.4236      nan      0.1000      0.0080
##     80      0.3381      nan      0.1000      0.0080
##    100      0.2756      nan      0.1000      0.0024
##    120      0.2318      nan      0.1000      0.0028
##    140      0.1974      nan      0.1000      0.0011
##    150      0.1825      nan      0.1000      0.0012
##
## Iter   TrainDeviance   ValidDeviance   StepSize   Improve
##      1      1.6094      nan      0.1000      0.1150
##      2      1.5366      nan      0.1000      0.0772
##      3      1.4882      nan      0.1000      0.0631
##      4      1.4483      nan      0.1000      0.0496
##      5      1.4169      nan      0.1000      0.0428
##      6      1.3873      nan      0.1000      0.0430
##      7      1.3588      nan      0.1000      0.0359
##      8      1.3349      nan      0.1000      0.0325
##      9      1.3138      nan      0.1000      0.0279
##     10      1.2947      nan      0.1000      0.0289
##     20      1.1435      nan      0.1000      0.0186

```

##	40	0.9704	nan	0.1000	0.0115
##	60	0.8590	nan	0.1000	0.0062
##	80	0.7741	nan	0.1000	0.0035
##	100	0.7069	nan	0.1000	0.0038
##	120	0.6538	nan	0.1000	0.0030
##	140	0.6081	nan	0.1000	0.0018
##	150	0.5860	nan	0.1000	0.0023
##					
##	Iter	TrainDeviance	ValidDeviance	StepSize	Improve
##	1	1.6094	nan	0.1000	0.1756
##	2	1.5002	nan	0.1000	0.1202
##	3	1.4265	nan	0.1000	0.0866
##	4	1.3722	nan	0.1000	0.0825
##	5	1.3205	nan	0.1000	0.0765
##	6	1.2739	nan	0.1000	0.0671
##	7	1.2329	nan	0.1000	0.0541
##	8	1.1988	nan	0.1000	0.0518
##	9	1.1664	nan	0.1000	0.0417
##	10	1.1390	nan	0.1000	0.0361
##	20	0.9423	nan	0.1000	0.0263
##	40	0.7056	nan	0.1000	0.0113
##	60	0.5674	nan	0.1000	0.0071
##	80	0.4797	nan	0.1000	0.0045
##	100	0.4063	nan	0.1000	0.0043
##	120	0.3505	nan	0.1000	0.0018
##	140	0.3112	nan	0.1000	0.0020
##	150	0.2922	nan	0.1000	0.0012
##					
##	Iter	TrainDeviance	ValidDeviance	StepSize	Improve
##	1	1.6094	nan	0.1000	0.2180
##	2	1.4736	nan	0.1000	0.1536
##	3	1.3804	nan	0.1000	0.1185
##	4	1.3062	nan	0.1000	0.0899
##	5	1.2498	nan	0.1000	0.0961
##	6	1.1928	nan	0.1000	0.0771
##	7	1.1447	nan	0.1000	0.0620
##	8	1.1058	nan	0.1000	0.0640
##	9	1.0658	nan	0.1000	0.0479
##	10	1.0349	nan	0.1000	0.0511
##	20	0.7917	nan	0.1000	0.0212
##	40	0.5368	nan	0.1000	0.0101
##	60	0.4135	nan	0.1000	0.0051
##	80	0.3287	nan	0.1000	0.0058
##	100	0.2690	nan	0.1000	0.0027
##	120	0.2277	nan	0.1000	0.0024
##	140	0.1944	nan	0.1000	0.0011
##	150	0.1795	nan	0.1000	0.0014
##					
##	Iter	TrainDeviance	ValidDeviance	StepSize	Improve
##	1	1.6094	nan	0.1000	0.2146
##	2	1.4757	nan	0.1000	0.1485
##	3	1.3811	nan	0.1000	0.1106
##	4	1.3123	nan	0.1000	0.1119
##	5	1.2441	nan	0.1000	0.0774


```
##      6      1.1955      nan      0.1000      0.0745
##      7      1.1499      nan      0.1000      0.0704
##      8      1.1072      nan      0.1000      0.0593
##      9      1.0705      nan      0.1000      0.0665
##     10      1.0303      nan      0.1000      0.0447
##     20      0.8057      nan      0.1000      0.0230
##     40      0.5561      nan      0.1000      0.0126
##     60      0.4186      nan      0.1000      0.0049
##     80      0.3371      nan      0.1000      0.0041
##    100      0.2748      nan      0.1000      0.0018
##    120      0.2315      nan      0.1000      0.0016
##    140      0.1983      nan      0.1000      0.0019
##    150      0.1833      nan      0.1000      0.0016
```

```
predict_gbm <- predict(model_gbm, subValidation)
print(confusionMatrix(predict_gbm, subValidation$classe), digits = 4)
```

```
## Confusion Matrix and Statistics
```

```
##
##           Reference
## Prediction    A    B    C    D    E
##           A 2199   50    0    3    0
##           B   21 1415   37    2   11
##           C    8   43 1308   45   11
##           D    4    1   21 1221   23
##           E    0    9    2   15 1397
```

```
## Overall Statistics
```

```
##
##           Accuracy : 0.961
##           95% CI : (0.9565, 0.9652)
##           No Information Rate : 0.2845
##           P-Value [Acc > NIR] : < 2.2e-16
```

```
##           Kappa : 0.9507
```

```
## McNemar's Test P-Value : NA
```

```
##
```

```
## Statistics by Class:
```

```
##
##           Class: A Class: B Class: C Class: D Class: E
## Sensitivity      0.9852   0.9321   0.9561   0.9495   0.9688
## Specificity      0.9906   0.9888   0.9835   0.9925   0.9959
## Pos Pred Value   0.9765   0.9522   0.9244   0.9614   0.9817
## Neg Pred Value   0.9941   0.9838   0.9907   0.9901   0.9930
## Prevalence       0.2845   0.1935   0.1744   0.1639   0.1838
## Detection Rate   0.2803   0.1803   0.1667   0.1556   0.1781
## Detection Prevalence 0.2870   0.1894   0.1803   0.1619   0.1814
## Balanced Accuracy 0.9879   0.9605   0.9698   0.9710   0.9824
```

```
varImp(model_gbm)
```

```
## gbm variable importance
```

```
##
```

```
##   only 20 most important variables shown (out of 51)
```

```
##
```

```
## Overall
## pitch_forearm 100.00
## yaw_belt 94.24
## accel_belt_z 84.35
## magnet_dumbbell_z 60.23
## gyros_belt_z 57.22
## magnet_belt_z 55.31
## magnet_dumbbell_y 54.35
## roll_forearm 45.10
## roll_dumbbell 34.03
## accel_forearm_x 27.89
## pitch_belt 27.57
## magnet_belt_y 22.16
## accel_dumbbell_y 20.60
## gyros_dumbbell_y 17.00
## accel_dumbbell_x 14.64
## yaw_arm 13.74
## magnet_forearm_z 12.90
## accel_forearm_z 12.87
## magnet_dumbbell_x 11.63
## magnet_arm_z 11.43
```

```
model_nnet<-train(x, y,
  preProcess = c("center","scale"),
  trControl = trainControl(method = "cv", number = 4),
  method='nnet')
```

```
## Loading required package: nnet
```

```
## # weights: 62
## initial value 15902.364919
## iter 10 value 13789.846536
## iter 20 value 13452.025887
## iter 30 value 12849.419305
## iter 40 value 12498.690544
## iter 50 value 12096.348695
## iter 60 value 11681.875575
## iter 70 value 11278.055360
## iter 80 value 10949.139001
## iter 90 value 10917.668411
## iter 100 value 10869.163543
## final value 10869.163543
## stopped after 100 iterations
## # weights: 176
## initial value 15333.277042
## iter 10 value 12303.507845
## iter 20 value 11013.944097
## iter 30 value 10166.099035
## iter 40 value 9773.899207
## iter 50 value 9436.758868
## iter 60 value 9088.988291
## iter 70 value 8776.168127
## iter 80 value 8534.154462
## iter 90 value 8367.342637
## iter 100 value 8253.957150
```

```

## final value 8253.957150
## stopped after 100 iterations
## # weights: 290
## initial value 16167.437462
## iter 10 value 11930.669686
## iter 20 value 9748.117569
## iter 30 value 8701.902876
## iter 40 value 8088.579850
## iter 50 value 7718.611424
## iter 60 value 7427.567320
## iter 70 value 7277.447288
## iter 80 value 7111.824854
## iter 90 value 6960.975225
## iter 100 value 6803.124635
## final value 6803.124635
## stopped after 100 iterations
## # weights: 62
## initial value 15002.904441
## iter 10 value 13270.405836
## iter 20 value 12809.610796
## iter 30 value 12410.372927
## iter 40 value 11984.710535
## iter 50 value 11584.468332
## iter 60 value 10982.381627
## iter 70 value 10778.608958
## iter 80 value 10553.998307
## iter 90 value 10433.382742
## iter 100 value 10386.128284
## final value 10386.128284
## stopped after 100 iterations
## # weights: 176
## initial value 14257.185047
## iter 10 value 12015.243486
## iter 20 value 10730.540033
## iter 30 value 9981.527977
## iter 40 value 9495.575822
## iter 50 value 9077.703826
## iter 60 value 8775.229514
## iter 70 value 8498.949415
## iter 80 value 8276.370152
## iter 90 value 8100.669979
## iter 100 value 7898.540413
## final value 7898.540413
## stopped after 100 iterations
## # weights: 290
## initial value 15560.296469
## iter 10 value 11736.861155
## iter 20 value 9502.130057
## iter 30 value 8519.053220
## iter 40 value 7784.473162
## iter 50 value 7185.597203
## iter 60 value 6727.892528
## iter 70 value 6488.287508
## iter 80 value 6267.880507

```

```

## iter 90 value 6089.425709
## iter 100 value 5931.963858
## final value 5931.963858
## stopped after 100 iterations
## # weights: 62
## initial value 14729.614973
## iter 10 value 13426.015889
## iter 20 value 12794.525680
## iter 30 value 12201.308480
## iter 40 value 11556.156774
## iter 50 value 11166.332026
## iter 60 value 10926.253400
## iter 70 value 10844.352556
## iter 80 value 10699.451369
## iter 90 value 10583.076578
## iter 100 value 10478.910575
## final value 10478.910575
## stopped after 100 iterations
## # weights: 176
## initial value 15870.550616
## iter 10 value 12455.329262
## iter 20 value 11141.831619
## iter 30 value 9787.003003
## iter 40 value 9353.409130
## iter 50 value 8933.300083
## iter 60 value 8699.610476
## iter 70 value 8541.660785
## iter 80 value 8441.115185
## iter 90 value 8269.914954
## iter 100 value 8062.829716
## final value 8062.829716
## stopped after 100 iterations
## # weights: 290
## initial value 16877.042833
## iter 10 value 11128.042282
## iter 20 value 8546.691177
## iter 30 value 7709.763733
## iter 40 value 7013.150498
## iter 50 value 6741.347243
## iter 60 value 6519.706973
## iter 70 value 6341.628899
## iter 80 value 6217.937097
## iter 90 value 6149.894295
## iter 100 value 6034.933817
## final value 6034.933817
## stopped after 100 iterations
## # weights: 62
## initial value 14975.624783
## iter 10 value 13912.860908
## iter 20 value 13490.636304
## iter 30 value 12815.150041
## iter 40 value 12236.707122
## iter 50 value 11760.883736
## iter 60 value 11300.532865

```

```

## iter 70 value 10949.687567
## iter 80 value 10836.952302
## iter 90 value 10751.839753
## iter 100 value 10628.710182
## final value 10628.710182
## stopped after 100 iterations
## # weights: 176
## initial value 14580.363234
## iter 10 value 12657.270805
## iter 20 value 11185.780568
## iter 30 value 10528.316232
## iter 40 value 10032.111752
## iter 50 value 9531.137565
## iter 60 value 8937.134844
## iter 70 value 8445.909084
## iter 80 value 8176.508882
## iter 90 value 8027.147401
## iter 100 value 7900.001238
## final value 7900.001238
## stopped after 100 iterations
## # weights: 290
## initial value 15844.472658
## iter 10 value 11707.632390
## iter 20 value 9707.514290
## iter 30 value 8485.589871
## iter 40 value 7610.395495
## iter 50 value 7041.835989
## iter 60 value 6766.276517
## iter 70 value 6591.277995
## iter 80 value 6505.250313
## iter 90 value 6326.063934
## iter 100 value 6201.007739
## final value 6201.007739
## stopped after 100 iterations
## # weights: 62
## initial value 14478.006615
## iter 10 value 13006.824260
## iter 20 value 12564.028874
## iter 30 value 12253.715430
## iter 40 value 12091.458408
## iter 50 value 11894.929511
## iter 60 value 11575.196163
## iter 70 value 11205.042094
## iter 80 value 10892.661279
## iter 90 value 10743.142766
## iter 100 value 10620.871917
## final value 10620.871917
## stopped after 100 iterations
## # weights: 176
## initial value 14372.696594
## iter 10 value 11359.128638
## iter 20 value 9942.708653
## iter 30 value 9403.347665
## iter 40 value 9115.046038

```

```

## iter 50 value 8857.291998
## iter 60 value 8638.097076
## iter 70 value 8450.860163
## iter 80 value 8294.291627
## iter 90 value 8097.605827
## iter 100 value 7982.060306
## final value 7982.060306
## stopped after 100 iterations
## # weights: 290
## initial value 14860.356421
## iter 10 value 11785.650360
## iter 20 value 9332.236560
## iter 30 value 8703.364189
## iter 40 value 8228.730311
## iter 50 value 7836.627186
## iter 60 value 7561.989848
## iter 70 value 7322.240820
## iter 80 value 7053.327249
## iter 90 value 6839.112866
## iter 100 value 6603.617869
## final value 6603.617869
## stopped after 100 iterations
## # weights: 62
## initial value 14906.641586
## iter 10 value 13207.142573
## iter 20 value 12352.298942
## iter 30 value 12021.405164
## iter 40 value 11781.035845
## iter 50 value 11599.690820
## iter 60 value 11431.582120
## iter 70 value 11306.750570
## iter 80 value 11189.125468
## iter 90 value 11089.083094
## iter 100 value 11052.346902
## final value 11052.346902
## stopped after 100 iterations
## # weights: 176
## initial value 15072.297236
## iter 10 value 11970.176500
## iter 20 value 10628.733275
## iter 30 value 10141.116835
## iter 40 value 9813.045204
## iter 50 value 9499.820224
## iter 60 value 9181.643358
## iter 70 value 8950.612507
## iter 80 value 8813.932238
## iter 90 value 8713.302919
## iter 100 value 8610.766783
## final value 8610.766783
## stopped after 100 iterations
## # weights: 290
## initial value 15915.709708
## iter 10 value 11778.307722
## iter 20 value 9538.066269

```

```

## iter 30 value 8280.489006
## iter 40 value 7693.251629
## iter 50 value 7347.898370
## iter 60 value 7133.272357
## iter 70 value 6996.875171
## iter 80 value 6835.770796
## iter 90 value 6725.672872
## iter 100 value 6668.593665
## final value 6668.593665
## stopped after 100 iterations
## # weights: 62
## initial value 14308.343981
## iter 10 value 13164.181605
## iter 20 value 12814.965367
## iter 30 value 12178.889219
## iter 40 value 11402.372681
## iter 50 value 11007.024738
## iter 60 value 10818.430612
## iter 70 value 10732.550285
## iter 80 value 10584.765500
## iter 90 value 10424.605941
## iter 100 value 10390.066765
## final value 10390.066765
## stopped after 100 iterations
## # weights: 176
## initial value 15633.684167
## iter 10 value 12179.478884
## iter 20 value 10897.288207
## iter 30 value 10097.290912
## iter 40 value 9670.483616
## iter 50 value 9236.758220
## iter 60 value 9047.895532
## iter 70 value 8823.798215
## iter 80 value 8576.792110
## iter 90 value 8387.485686
## iter 100 value 8240.886243
## final value 8240.886243
## stopped after 100 iterations
## # weights: 290
## initial value 17008.826840
## iter 10 value 12514.527013
## iter 20 value 10039.284937
## iter 30 value 8896.362979
## iter 40 value 8276.879074
## iter 50 value 7968.172612
## iter 60 value 7711.012970
## iter 70 value 7507.478782
## iter 80 value 7313.890916
## iter 90 value 7177.334054
## iter 100 value 7070.471335
## final value 7070.471335
## stopped after 100 iterations
## # weights: 62
## initial value 14719.601802

```

```

## iter 10 value 13605.527774
## iter 20 value 13072.075584
## iter 30 value 12268.161809
## iter 40 value 11624.229937
## iter 50 value 11244.367438
## iter 60 value 11072.211215
## iter 70 value 10892.717964
## iter 80 value 10704.974893
## iter 90 value 10565.466793
## iter 100 value 10464.129103
## final value 10464.129103
## stopped after 100 iterations
## # weights: 176
## initial value 14891.385239
## iter 10 value 12165.302124
## iter 20 value 10667.276636
## iter 30 value 10113.709390
## iter 40 value 9840.030643
## iter 50 value 9395.431347
## iter 60 value 9081.347769
## iter 70 value 8890.271169
## iter 80 value 8738.785109
## iter 90 value 8498.203404
## iter 100 value 8325.776525
## final value 8325.776525
## stopped after 100 iterations
## # weights: 290
## initial value 14925.639650
## iter 10 value 11843.478010
## iter 20 value 9745.744640
## iter 30 value 8938.958900
## iter 40 value 8182.381036
## iter 50 value 7687.673959
## iter 60 value 7369.606537
## iter 70 value 7162.279194
## iter 80 value 6985.350701
## iter 90 value 6806.649513
## iter 100 value 6660.286733
## final value 6660.286733
## stopped after 100 iterations
## # weights: 62
## initial value 14536.692342
## iter 10 value 13433.641211
## iter 20 value 12880.861366
## iter 30 value 12177.726910
## iter 40 value 11642.830111
## iter 50 value 11264.185056
## iter 60 value 11055.975838
## iter 70 value 11012.941670
## iter 80 value 10940.762045
## iter 90 value 10763.999646
## iter 100 value 10633.558005
## final value 10633.558005
## stopped after 100 iterations

```



```

## # weights: 176
## initial value 14834.846053
## iter 10 value 12249.807821
## iter 20 value 10744.202715
## iter 30 value 9974.729355
## iter 40 value 9700.363730
## iter 50 value 9496.244242
## iter 60 value 9313.602003
## iter 70 value 8952.419712
## iter 80 value 8620.900421
## iter 90 value 8336.818002
## iter 100 value 8138.985705
## final value 8138.985705
## stopped after 100 iterations
## # weights: 290
## initial value 16996.568163
## iter 10 value 11477.254495
## iter 20 value 9480.355687
## iter 30 value 8733.843046
## iter 40 value 7821.548683
## iter 50 value 7272.492469
## iter 60 value 6838.975172
## iter 70 value 6482.418626
## iter 80 value 6207.467897
## iter 90 value 6059.449087
## iter 100 value 5933.016624
## final value 5933.016624
## stopped after 100 iterations
## # weights: 62
## initial value 14821.222108
## iter 10 value 13536.269991
## iter 20 value 12695.500645
## iter 30 value 12301.494453
## iter 40 value 11958.064599
## iter 50 value 11707.243271
## iter 60 value 11399.600448
## iter 70 value 11259.027114
## iter 80 value 11046.015418
## iter 90 value 10885.969439
## iter 100 value 10831.744062
## final value 10831.744062
## stopped after 100 iterations
## # weights: 176
## initial value 16073.799717
## iter 10 value 11968.614844
## iter 20 value 10757.940394
## iter 30 value 10130.703315
## iter 40 value 9623.716620
## iter 50 value 9145.531362
## iter 60 value 8914.883392
## iter 70 value 8734.135182
## iter 80 value 8546.948925
## iter 90 value 8398.366894
## iter 100 value 8301.973187

```

```

## final value 8301.973187
## stopped after 100 iterations
## # weights: 290
## initial value 14877.442910
## iter 10 value 11594.672948
## iter 20 value 9742.172158
## iter 30 value 8762.720413
## iter 40 value 8118.063875
## iter 50 value 7819.579503
## iter 60 value 7608.431873
## iter 70 value 7372.300981
## iter 80 value 7184.778638
## iter 90 value 7034.740535
## iter 100 value 6918.419447
## final value 6918.419447
## stopped after 100 iterations
## # weights: 62
## initial value 14202.873769
## iter 10 value 13178.132290
## iter 20 value 12863.461177
## iter 30 value 12209.536181
## iter 40 value 11565.353133
## iter 50 value 11186.738993
## iter 60 value 10968.209236
## iter 70 value 10805.745992
## iter 80 value 10596.392313
## iter 90 value 10515.691673
## iter 100 value 10477.671322
## final value 10477.671322
## stopped after 100 iterations
## # weights: 176
## initial value 17149.819558
## iter 10 value 12077.561516
## iter 20 value 10614.130844
## iter 30 value 9851.947014
## iter 40 value 9421.617343
## iter 50 value 8976.199610
## iter 60 value 8671.224726
## iter 70 value 8452.408069
## iter 80 value 8297.978103
## iter 90 value 8160.791345
## iter 100 value 8015.014190
## final value 8015.014190
## stopped after 100 iterations
## # weights: 290
## initial value 15408.647705
## iter 10 value 11465.566884
## iter 20 value 9323.081364
## iter 30 value 8337.657709
## iter 40 value 7972.877981
## iter 50 value 7717.435436
## iter 60 value 7321.082036
## iter 70 value 7003.400360
## iter 80 value 6788.663078

```

```

## iter 90 value 6631.556418
## iter 100 value 6537.297244
## final value 6537.297244
## stopped after 100 iterations
## # weights: 62
## initial value 14565.337268
## iter 10 value 13520.059937
## iter 20 value 13309.965591
## iter 30 value 13072.262047
## iter 40 value 12596.230497
## iter 50 value 11729.655307
## iter 60 value 11021.910766
## iter 70 value 10756.966009
## iter 80 value 10663.663177
## iter 90 value 10495.729645
## iter 100 value 10426.886689
## final value 10426.886689
## stopped after 100 iterations
## # weights: 176
## initial value 16370.961965
## iter 10 value 12438.965918
## iter 20 value 10557.705298
## iter 30 value 9783.251378
## iter 40 value 9269.176718
## iter 50 value 9019.539237
## iter 60 value 8729.129208
## iter 70 value 8446.942588
## iter 80 value 8242.884563
## iter 90 value 8054.357399
## iter 100 value 7930.703031
## final value 7930.703031
## stopped after 100 iterations
## # weights: 290
## initial value 16355.086642
## iter 10 value 11994.977817
## iter 20 value 9636.574092
## iter 30 value 8786.884517
## iter 40 value 8123.818489
## iter 50 value 7756.418867
## iter 60 value 7515.060595
## iter 70 value 7285.822621
## iter 80 value 7183.660602
## iter 90 value 7058.225563
## iter 100 value 6892.142988
## final value 6892.142988
## stopped after 100 iterations
## # weights: 290
## initial value 21369.680065
## iter 10 value 16065.777912
## iter 20 value 13215.698272
## iter 30 value 12025.403093
## iter 40 value 11063.337157
## iter 50 value 10406.434663
## iter 60 value 9835.789214

```

```
## iter 70 value 9350.812011
## iter 80 value 9001.631389
## iter 90 value 8735.195387
## iter 100 value 8534.090758
## final value 8534.090758
## stopped after 100 iterations

predict_nnet <- predict(model_nnet, subValidation)
print(confusionMatrix(predict_nnet, subValidation$classe), digits = 2)
```

```
## Confusion Matrix and Statistics
```

```
##
##           Reference
## Prediction   A    B    C    D    E
##           A 1871  142   42  130   8
##           B   27  895  116   36 160
##           C  236  373 1119  168 140
##           D   92   24   13  848 102
##           E    6   84   78  104 1032
```

```
##
```

```
## Overall Statistics
```

```
##
##           Accuracy : 0.73
##           95% CI : (0.72, 0.74)
##           No Information Rate : 0.28
##           P-Value [Acc > NIR] : <2e-16
```

```
##
```

```
##           Kappa : 0.66
##           McNemar's Test P-Value : <2e-16
```

```
##
```

```
## Statistics by Class:
```

```
##
```

	Class: A	Class: B	Class: C	Class: D	Class: E
## Sensitivity	0.84	0.59	0.82	0.66	0.72
## Specificity	0.94	0.95	0.86	0.96	0.96
## Pos Pred Value	0.85	0.73	0.55	0.79	0.79
## Neg Pred Value	0.94	0.91	0.96	0.94	0.94
## Prevalence	0.28	0.19	0.17	0.16	0.18
## Detection Rate	0.24	0.11	0.14	0.11	0.13
## Detection Prevalence	0.28	0.16	0.26	0.14	0.17
## Balanced Accuracy	0.89	0.77	0.84	0.81	0.84

```
varImp(model_nnet)
```

```
## nnet variable importance
```

```
##
```

```
## variables are sorted by maximum importance across the classes
## only 20 most important variables shown (out of 51)
```

```
##
```

	Overall	A	B	C	D	E
## yaw_belt	100.00	100.00	100.00	100.00	100.00	100.00
## accel_belt_z	72.25	72.25	72.25	72.25	72.25	72.25
## accel_dumbbell_z	60.59	60.59	60.59	60.59	60.59	60.59
## total_accel_belt	52.13	52.13	52.13	52.13	52.13	52.13
## magnet_dumbbell_z	47.84	47.84	47.84	47.84	47.84	47.84

```
## magnet_belt_y      40.59  40.59  40.59  40.59  40.59  40.59
## accel_arm_x        38.97  38.97  38.97  38.97  38.97  38.97
## magnet_dumbbell_x  38.88  38.88  38.88  38.88  38.88  38.88
## magnet_arm_z       38.36  38.36  38.36  38.36  38.36  38.36
## accel_arm_z        33.38  33.38  33.38  33.38  33.38  33.38
## magnet_arm_y       33.09  33.09  33.09  33.09  33.09  33.09
## accel_dumbbell_x   32.55  32.55  32.55  32.55  32.55  32.55
## accel_dumbbell_y   30.40  30.40  30.40  30.40  30.40  30.40
## accel_forearm_z    30.27  30.27  30.27  30.27  30.27  30.27
## pitch_forearm      29.23  29.23  29.23  29.23  29.23  29.23
## accel_belt_x       26.07  26.07  26.07  26.07  26.07  26.07
## accel_belt_y       25.56  25.56  25.56  25.56  25.56  25.56
## total_accel_dumbbell 25.55  25.55  25.55  25.55  25.55  25.55
## magnet_forearm_y   25.49  25.49  25.49  25.49  25.49  25.49
## magnet_dumbbell_y  23.47  23.47  23.47  23.47  23.47  23.47
```

Evaluating all the models, the randomForest models seems to enable the best fit and that is what we will use to estimate the final result.

Final Result & OOS Error

```
print(predict(model_rf, newdata=subTest))
```

```
## [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
```

Next the out of sample error is computed

```
Acc.OOSErr <- sum(predict_rf != subValidation$classe)*100 / length(predict_rf)

cat("The OOS error is: ", format(Acc.OOSErr, digits = 4), "%", sep="")
```

```
## The OOS error is: 0.7392%
```

Please do let me know if there is some other analysis that needs to be covered.