Activity Monitor Study

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This is a summary for predicting the manner in which six (6) people performed barbell lifts correctly and incorrectly in five (5) different ways, stored in the classe variable.

The goal was to use the data from accelerometers on the belt, forearm, arm, and dumbell of the test subjects given in a training data set and a test data set.

Data Processing

First we will import the data and look at the data set for unusual values.

Notcied there are several variables that are NA and other variables that do not significantly change in the training data set. Since there are 160 variables, we will clean the data and remove variables that

1. Have significant amount of NA values
2. Have very little variation, use the nearZeroVar function.
3. Variables that are used for identification such as Time Stamps, ID numbers, etc…

```
#load the training dataset into pml.training
pml.training <- read.csv("~/pml-training.csv")
#load the test dataset into pml.testing
pml.testing <- read.csv("~/pml-testing.csv")

str(pml.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 1323
084232 1323084232 1323084232 1323084232 1323084232 1323084232 ...
##  $ raw_timestamp_part_2    : int  788290 808298 820366 120339 196328 304277 368296
440390 484323 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 1.4
5 ...
##  $ pitch_belt              : num  8.07 8.07 8.07 8.05 8.07 8.06 8.09 8.13 8.16 8.1
7 ...
```

```
##  $ 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/ 397 levels "","-0.016850",..: 1 1 1 1 1 1 1
1 1 1 ...
##  $ kurtosis_picth_belt    : Factor w/ 317 levels "","-0.021887",..: 1 1 1 1 1 1 1
1 1 1 ...
##  $ kurtosis_yaw_belt      : Factor w/ 2 levels "","#DIV/0!": 1 1 1 1 1 1 1 1 1 1
...
##  $ skewness_roll_belt     : Factor w/ 395 levels "","-0.003095",..: 1 1 1 1 1 1 1
1 1 1 ...
##  $ skewness_roll_belt.1   : Factor w/ 338 levels "","-0.005928",..: 1 1 1 1 1 1 1
1 1 1 ...
##  $ skewness_yaw_belt      : Factor w/ 2 levels "","#DIV/0!": 1 1 1 1 1 1 1 1 1 1
...
##  $ 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/ 68 levels "","-0.1","-0.2",..: 1 1 1 1 1 1
1 1 1 1 ...
##  $ 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/ 68 levels "","-0.1","-0.2",..: 1 1 1 1 1 1
1 1 1 1 ...
##  $ 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/ 4 levels "","#DIV/0!","0.00",..: 1 1 1 1 1
1 1 1 1 1 ...
##  $ 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 -30
8 ...
##  $ roll_arm               : num  -128 -128 -128 -128 -128 -128 -128 -128 -128 -12
8 ...
```

```
##  $ 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 -16
1 ...
##  $ 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 -0.0
3 -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 -28
8 ...
##  $ 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 -12
4 ...
##  $ magnet_arm_x            : int  -368 -369 -368 -372 -374 -369 -373 -372 -369 -37
6 ...
##  $ 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/ 330 levels "","-0.02438",..: 1 1 1 1 1 1 1
1 1 1 ...
##  $ kurtosis_picth_arm      : Factor w/ 328 levels "","-0.00484",..: 1 1 1 1 1 1 1
1 1 1 ...
##  $ kurtosis_yaw_arm        : Factor w/ 395 levels "","-0.01548",..: 1 1 1 1 1 1 1
1 1 1 ...
##  $ skewness_roll_arm       : Factor w/ 331 levels "","-0.00051",..: 1 1 1 1 1 1 1
1 1 1 ...
##  $ skewness_pitch_arm      : Factor w/ 328 levels "","-0.00184",..: 1 1 1 1 1 1 1
1 1 1 ...
##  $ skewness_yaw_arm        : Factor w/ 395 levels "","-0.00311",..: 1 1 1 1 1 1 1
1 1 1 ...
##  $ 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/ 398 levels "","-0.0035","-0.0073",..: 1 1 1
1 1 1 1 1 1 1 ...
##  $ kurtosis_picth_dumbbell : Factor w/ 401 levels "","-0.0163","-0.0233",..: 1 1 1
1 1 1 1 1 1 1 ...
##  $ kurtosis_yaw_dumbbell   : Factor w/ 2 levels "","#DIV/0!": 1 1 1 1 1 1 1 1 1 1
...
##  $ skewness_roll_dumbbell  : Factor w/ 401 levels "","-0.0082","-0.0096",..: 1 1 1
1 1 1 1 1 1 1 ...
##  $ skewness_pitch_dumbbell : Factor w/ 402 levels "","-0.0053","-0.0084",..: 1 1 1
1 1 1 1 1 1 1 ...
##  $ skewness_yaw_dumbbell   : Factor w/ 2 levels "","#DIV/0!": 1 1 1 1 1 1 1 1 1 1
...
##  $ 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/ 73 levels "","-0.1","-0.2",..: 1 1 1 1 1 1
1 1 1 1 ...
##  $ 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/ 73 levels "","-0.1","-0.2",..: 1 1 1 1 1 1
1 1 1 1 ...
##  $ amplitude_roll_dumbbell : num  NA NA NA NA NA NA NA NA NA NA ...
##   [list output truncated]
```

```
names(pml.training)
```

```
##   [1] "X"                        "user_name"
##   [3] "raw_timestamp_part_1"     "raw_timestamp_part_2"
##   [5] "cvtd_timestamp"           "new_window"
##   [7] "num_window"               "roll_belt"
##   [9] "pitch_belt"               "yaw_belt"
##  [11] "total_accel_belt"         "kurtosis_roll_belt"
##  [13] "kurtosis_picth_belt"      "kurtosis_yaw_belt"
##  [15] "skewness_roll_belt"       "skewness_roll_belt.1"
##  [17] "skewness_yaw_belt"        "max_roll_belt"
##  [19] "max_picth_belt"           "max_yaw_belt"
##  [21] "min_roll_belt"            "min_pitch_belt"
##  [23] "min_yaw_belt"             "amplitude_roll_belt"
##  [25] "amplitude_pitch_belt"     "amplitude_yaw_belt"
##  [27] "var_total_accel_belt"     "avg_roll_belt"
##  [29] "stddev_roll_belt"         "var_roll_belt"
##  [31] "avg_pitch_belt"           "stddev_pitch_belt"
##  [33] "var_pitch_belt"           "avg_yaw_belt"
##  [35] "stddev_yaw_belt"          "var_yaw_belt"
##  [37] "gyros_belt_x"             "gyros_belt_y"
##  [39] "gyros_belt_z"             "accel_belt_x"
##  [41] "accel_belt_y"             "accel_belt_z"
##  [43] "magnet_belt_x"            "magnet_belt_y"
```

```
##  [45] "magnet_belt_z"            "roll_arm"
##  [47] "pitch_arm"                "yaw_arm"
##  [49] "total_accel_arm"          "var_accel_arm"
##  [51] "avg_roll_arm"             "stddev_roll_arm"
##  [53] "var_roll_arm"             "avg_pitch_arm"
##  [55] "stddev_pitch_arm"         "var_pitch_arm"
##  [57] "avg_yaw_arm"              "stddev_yaw_arm"
##  [59] "var_yaw_arm"              "gyros_arm_x"
##  [61] "gyros_arm_y"              "gyros_arm_z"
##  [63] "accel_arm_x"              "accel_arm_y"
##  [65] "accel_arm_z"              "magnet_arm_x"
##  [67] "magnet_arm_y"             "magnet_arm_z"
##  [69] "kurtosis_roll_arm"        "kurtosis_picth_arm"
##  [71] "kurtosis_yaw_arm"         "skewness_roll_arm"
##  [73] "skewness_pitch_arm"       "skewness_yaw_arm"
##  [75] "max_roll_arm"             "max_picth_arm"
##  [77] "max_yaw_arm"              "min_roll_arm"
##  [79] "min_pitch_arm"            "min_yaw_arm"
##  [81] "amplitude_roll_arm"       "amplitude_pitch_arm"
##  [83] "amplitude_yaw_arm"        "roll_dumbbell"
##  [85] "pitch_dumbbell"           "yaw_dumbbell"
##  [87] "kurtosis_roll_dumbbell"   "kurtosis_picth_dumbbell"
##  [89] "kurtosis_yaw_dumbbell"    "skewness_roll_dumbbell"
##  [91] "skewness_pitch_dumbbell"  "skewness_yaw_dumbbell"
##  [93] "max_roll_dumbbell"        "max_picth_dumbbell"
##  [95] "max_yaw_dumbbell"         "min_roll_dumbbell"
##  [97] "min_pitch_dumbbell"       "min_yaw_dumbbell"
##  [99] "amplitude_roll_dumbbell"  "amplitude_pitch_dumbbell"
## [101] "amplitude_yaw_dumbbell"   "total_accel_dumbbell"
## [103] "var_accel_dumbbell"       "avg_roll_dumbbell"
## [105] "stddev_roll_dumbbell"     "var_roll_dumbbell"
## [107] "avg_pitch_dumbbell"       "stddev_pitch_dumbbell"
## [109] "var_pitch_dumbbell"       "avg_yaw_dumbbell"
## [111] "stddev_yaw_dumbbell"      "var_yaw_dumbbell"
## [113] "gyros_dumbbell_x"         "gyros_dumbbell_y"
## [115] "gyros_dumbbell_z"         "accel_dumbbell_x"
## [117] "accel_dumbbell_y"         "accel_dumbbell_z"
## [119] "magnet_dumbbell_x"        "magnet_dumbbell_y"
## [121] "magnet_dumbbell_z"        "roll_forearm"
## [123] "pitch_forearm"            "yaw_forearm"
## [125] "kurtosis_roll_forearm"    "kurtosis_picth_forearm"
## [127] "kurtosis_yaw_forearm"     "skewness_roll_forearm"
## [129] "skewness_pitch_forearm"   "skewness_yaw_forearm"
## [131] "max_roll_forearm"         "max_picth_forearm"
## [133] "max_yaw_forearm"          "min_roll_forearm"
## [135] "min_pitch_forearm"        "min_yaw_forearm"
## [137] "amplitude_roll_forearm"   "amplitude_pitch_forearm"
## [139] "amplitude_yaw_forearm"    "total_accel_forearm"
## [141] "var_accel_forearm"        "avg_roll_forearm"
## [143] "stddev_roll_forearm"      "var_roll_forearm"
```

```
## [145] "avg_pitch_forearm"        "stddev_pitch_forearm"
## [147] "var_pitch_forearm"        "avg_yaw_forearm"
## [149] "stddev_yaw_forearm"       "var_yaw_forearm"
## [151] "gyros_forearm_x"          "gyros_forearm_y"
## [153] "gyros_forearm_z"          "accel_forearm_x"
## [155] "accel_forearm_y"          "accel_forearm_z"
## [157] "magnet_forearm_x"         "magnet_forearm_y"
## [159] "magnet_forearm_z"         "classe"
```

```
head(pml.training[,160])
```

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

```
tail(pml.training[,160])
```

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

```
str(pml.training$classe)
```

```
##  Factor w/ 5 levels "A","B","C","D",..: 1 1 1 1 1 1 1 1 1 1 ...
```

```
hist(as.integer(pml.training$classe))

dim(pml.training)
```

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

```
dim(pml.testing)
```

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

```
#use the testing data set as a validation since it is only 20 data points veruse 1962
2 data points.

library(caret)
```

```
## Warning: package 'caret' was built under R version 3.1.3
```

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

```
## Warning: package 'lattice' was built under R version 3.1.3
```

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

```
## Warning: package 'ggplot2' was built under R version 3.1.3
```


```
#creaet a training set from the training dataset.
inTrain <- createDataPartition(y=pml.training$classe, p=0.7, list=FALSE)
training <- pml.training[inTrain,]; testing <- pml.training[-inTrain,]

dim(training)
```

```
## [1] 13737   160
```

```
summary(training)
```

```
##        X            user_name    raw_timestamp_part_1 raw_timestamp_part_2
##  Min.   :    1   adelmo  :2747   Min.   :1.322e+09    Min.   :   294
##  1st Qu.: 4907   carlitos:2185   1st Qu.:1.323e+09    1st Qu.:256300
##  Median : 9839   charles :2484   Median :1.323e+09    Median :500309
##  Mean   : 9820   eurico  :2164   Mean   :1.323e+09    Mean   :502274
##  3rd Qu.:14737   jeremy  :2348   3rd Qu.:1.323e+09    3rd Qu.:754725
##  Max.   :19621   pedro   :1809   Max.   :1.323e+09    Max.   :998801
##
##           cvtd_timestamp new_window    num_window    roll_belt
##  28/11/2011 14:14:1069   no :13459   Min.   :  1   Min.   :-28.90
##  05/12/2011 11:24:1057   yes:  278   1st Qu.:224   1st Qu.:  1.10
##  05/12/2011 11:25:1007               Median :425   Median :114.00
##  30/11/2011 17:11: 995               Mean   :432   Mean   : 64.54
##  02/12/2011 14:57: 978               3rd Qu.:645   3rd Qu.:123.00
##  02/12/2011 13:34: 966               Max.   :864   Max.   :162.00
##  (Other)         :7665
##    pitch_belt          yaw_belt       total_accel_belt kurtosis_roll_belt
##  Min.   :-54.9000   Min.   :-179.00   Min.   : 0.00             :13459
##  1st Qu.:  1.7200   1st Qu.: -88.30   1st Qu.: 3.00    #DIV/0!  :    6
##  Median :  5.2800   Median : -12.60   Median :17.00    -0.016850:    1
##  Mean   :  0.2153   Mean   : -10.73   Mean   :11.32    -0.021024:    1
##  3rd Qu.: 14.9000   3rd Qu.:  14.00   3rd Qu.:18.00    -0.025513:    1
##  Max.   : 60.3000   Max.   : 179.00   Max.   :28.00    -0.060160:    1
##                                                        (Other)  :  268
##  kurtosis_picth_belt kurtosis_yaw_belt skewness_roll_belt
##            :13459            :13459             :13459
##  #DIV/0!  :   24     #DIV/0!:  278     #DIV/0!  :    5
##  -0.684748:    2                       0.000000 :    2
##  -0.686349:    2                       -0.003095:    1
##  -0.758615:    2                       -0.010002:    1
##  -1.122700:    2                       -0.014020:    1
##  (Other)  :  246                       (Other)  :  268
##  skewness_roll_belt.1 skewness_yaw_belt max_roll_belt     max_picth_belt
##            :13459             :13459     Min.   :-94.100   Min.   : 3.00
##  #DIV/0!  :   24      #DIV/0!:  278     1st Qu.:-87.900   1st Qu.: 5.00
##  -0.587156:    2                       Median : -4.900   Median :18.00
##  -0.733570:    2                       Mean   : -7.756   Mean   :13.08
##  -1.159179:    2                       3rd Qu.: 12.750   3rd Qu.:19.00
##  -1.708728:    2                       Max.   :180.000   Max.   :28.00
##  (Other)  :  246                       NA's   :13459     NA's   :13459
##   max_yaw_belt   min_roll_belt     min_pitch_belt   min_yaw_belt
##          :13459   Min.   :-180.00   Min.   : 0.00           :13459
##  -1.1    :   22   1st Qu.: -88.30   1st Qu.: 3.00   -1.1    :   22
##  -1.2    :   19   Median :  -7.45   Median :16.00   -1.2    :   19
##  -1.4    :   17   Mean   : -11.07   Mean   :10.85   -1.4    :   17
##  -1.3    :   15   3rd Qu.:   3.40   3rd Qu.:17.00   -1.3    :   15
##  -0.9    :   14   Max.   : 173.00   Max.   :23.00   -0.9    :   14
##  (Other):  191   NA's   :13459     NA's   :13459   (Other):  191
##  amplitude_roll_belt amplitude_pitch_belt amplitude_yaw_belt
##  Min.   :  0.000     Min.   : 0.000              :13459
```

```
##  1st Qu.:  0.400     1st Qu.: 1.000       #DIV/0!:    6
##  Median :  1.000     Median : 1.000       0.00   :    7
##  Mean   :  3.311     Mean   : 2.227       0.0000 :  265
##  3rd Qu.:  2.022     3rd Qu.: 2.000
##  Max.   :360.000     Max.   :12.000
##  NA's   :13459       NA's   :13459
##  var_total_accel_belt avg_roll_belt    stddev_roll_belt var_roll_belt
##  Min.   : 0.000        Min.   :-27.40   Min.   : 0.000   Min.   :  0.000
##  1st Qu.: 0.100        1st Qu.:  1.10   1st Qu.: 0.200   1st Qu.:  0.000
##  Median : 0.200        Median :116.40   Median : 0.400   Median :  0.100
##  Mean   : 0.979        Mean   : 68.79   Mean   : 1.419   Mean   :  8.465
##  3rd Qu.: 0.300        3rd Qu.:122.83   3rd Qu.: 0.700   3rd Qu.:  0.500
##  Max.   :16.500        Max.   :157.40   Max.   :13.300   Max.   :177.200
##  NA's   :13459         NA's   :13459    NA's   :13459    NA's   :13459
##  avg_pitch_belt    stddev_pitch_belt var_pitch_belt   avg_yaw_belt
##  Min.   :-51.400   Min.   :0.000     Min.   :0.000   Min.   :-138.300
##  1st Qu.:  2.200   1st Qu.:0.200     1st Qu.:0.000   1st Qu.: -88.100
##  Median :  5.600   Median :0.400     Median :0.100   Median :  -5.900
##  Mean   :  1.161   Mean   :0.599     Mean   :0.716   Mean   :  -9.894
##  3rd Qu.: 15.875   3rd Qu.:0.700     3rd Qu.:0.500   3rd Qu.:   6.000
##  Max.   : 59.700   Max.   :3.100     Max.   :9.300   Max.   : 173.400
##  NA's   :13459     NA's   :13459     NA's   :13459   NA's   :13459
##  stddev_yaw_belt    var_yaw_belt        gyros_belt_x
##  Min.   :  0.000   Min.   :    0.000   Min.   :-1.04000
##  1st Qu.:  0.100   1st Qu.:    0.010   1st Qu.:-0.03000
##  Median :  0.300   Median :    0.110   Median : 0.03000
##  Mean   :  1.037   Mean   :   44.220   Mean   :-0.00508
##  3rd Qu.:  0.700   3rd Qu.:    0.498   3rd Qu.: 0.11000
##  Max.   :109.200   Max.   :11928.470   Max.   : 2.22000
##  NA's   :13459     NA's   :13459
##   gyros_belt_y       gyros_belt_z      accel_belt_x      accel_belt_y
##  Min.   :-0.64000   Min.   :-1.4600   Min.   :-82.000   Min.   :-65.00
##  1st Qu.: 0.00000   1st Qu.:-0.2000   1st Qu.:-21.000   1st Qu.:  3.00
##  Median : 0.02000   Median :-0.1000   Median :-15.000   Median : 35.00
##  Mean   : 0.03981   Mean   :-0.1304   Mean   : -5.479   Mean   : 30.17
##  3rd Qu.: 0.11000   3rd Qu.:-0.0200   3rd Qu.: -5.000   3rd Qu.: 61.00
##  Max.   : 0.64000   Max.   : 1.6200   Max.   : 85.000   Max.   :121.00
##
##   accel_belt_z     magnet_belt_x    magnet_belt_y   magnet_belt_z
##  Min.   :-266.00   Min.   :-52.00   Min.   :359.0   Min.   :-623.0
##  1st Qu.:-162.00   1st Qu.:  9.00   1st Qu.:581.0   1st Qu.:-375.0
##  Median :-153.00   Median : 35.00   Median :601.0   Median :-320.0
##  Mean   : -72.83   Mean   : 55.75   Mean   :593.5   Mean   :-345.6
##  3rd Qu.:  27.00   3rd Qu.: 60.00   3rd Qu.:610.0   3rd Qu.:-306.0
##  Max.   : 103.00   Max.   :481.00   Max.   :669.0   Max.   : 293.0
##
##     roll_arm         pitch_arm          yaw_arm          total_accel_arm
##  Min.   :-180.00   Min.   :-88.200   Min.   :-180.0000   Min.   : 1.00
##  1st Qu.: -32.10   1st Qu.:-26.100   1st Qu.: -43.3000   1st Qu.:17.00
##  Median :   0.00   Median :  0.000   Median :   0.0000   Median :27.00
```

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##  Mean   :  17.77   Mean   : -4.678   Mean   :  -0.7218   Mean   :25.52
##  3rd Qu.:  77.00   3rd Qu.: 11.100   3rd Qu.:  46.0000   3rd Qu.:33.00
##  Max.   : 180.00   Max.   : 88.500   Max.   : 180.0000   Max.   :65.00
##
##  var_accel_arm      avg_roll_arm     stddev_roll_arm    var_roll_arm
##  Min.   :  0.000   Min.   :-166.67   Min.   :  0.000   Min.   :    0.000
##  1st Qu.:  9.021   1st Qu.: -38.32   1st Qu.:  1.280   1st Qu.:    1.637
##  Median : 41.123   Median :   0.00   Median :  5.833   Median :   34.034
##  Mean   : 54.250   Mean   :  10.82   Mean   : 10.636   Mean   :  335.598
##  3rd Qu.: 81.036   3rd Qu.:  73.25   3rd Qu.: 14.747   3rd Qu.:  217.506
##  Max.   :253.010   Max.   : 160.78   Max.   :161.452   Max.   :26066.575
##  NA's   :13459     NA's   :13459     NA's   :13459     NA's   :13459
##  avg_pitch_arm     stddev_pitch_arm var_pitch_arm       avg_yaw_arm
##  Min.   :-81.773   Min.   : 0.000   Min.   :   0.000   Min.   :-173.440
##  1st Qu.:-21.717   1st Qu.: 1.703   1st Qu.:   2.902   1st Qu.: -32.179
##  Median :  0.000   Median : 8.084   Median :  65.351   Median :   0.000
##  Mean   : -4.607   Mean   :10.489   Mean   : 200.895   Mean   :  -0.445
##  3rd Qu.:  7.326   3rd Qu.:16.327   3rd Qu.: 266.576   3rd Qu.:  34.657
##  Max.   : 75.659   Max.   :43.412   Max.   :1884.565   Max.   : 152.000
##  NA's   :13459     NA's   :13459    NA's   :13459      NA's   :13459
##  stddev_yaw_arm    var_yaw_arm         gyros_arm_x        gyros_arm_y
##  Min.   :  0.00   Min.   :    0.000   Min.   :-6.37000   Min.   :-3.4400
##  1st Qu.:  2.38   1st Qu.:    5.724   1st Qu.:-1.36000   1st Qu.:-0.7900
##  Median : 16.45   Median :  270.751   Median : 0.06000   Median :-0.2400
##  Mean   : 22.37   Mean   : 1039.526   Mean   : 0.02997   Mean   :-0.2542
##  3rd Qu.: 36.62   3rd Qu.: 1341.341   3rd Qu.: 1.56000   3rd Qu.: 0.1600
##  Max.   :177.04   Max.   :31344.568   Max.   : 4.87000   Max.   : 2.8400
##  NA's   :13459    NA's   :13459
##   gyros_arm_z       accel_arm_x       accel_arm_y       accel_arm_z
##  Min.   :-2.3300   Min.   :-383.00   Min.   :-318.00   Min.   :-630.00
##  1st Qu.:-0.0700   1st Qu.:-242.00   1st Qu.: -54.00   1st Qu.:-141.00
##  Median : 0.2500   Median : -45.00   Median :  13.00   Median : -46.00
##  Mean   : 0.2718   Mean   : -60.46   Mean   :  32.33   Mean   : -70.93
##  3rd Qu.: 0.7200   3rd Qu.:  83.00   3rd Qu.: 139.00   3rd Qu.:  23.00
##  Max.   : 2.9500   Max.   : 435.00   Max.   : 303.00   Max.   : 271.00
##
##   magnet_arm_x     magnet_arm_y     magnet_arm_z    kurtosis_roll_arm
##  Min.   :-584.0   Min.   :-392.0   Min.   :-597.0           :13459
##  1st Qu.:-300.0   1st Qu.:  -9.0   1st Qu.: 133.0   #DIV/0! :   56
##  Median : 287.0   Median : 200.0   Median : 444.0   -0.05051:    1
##  Mean   : 192.1   Mean   : 156.2   Mean   : 307.4   -0.08050:    1
##  3rd Qu.: 638.0   3rd Qu.: 323.0   3rd Qu.: 545.0   -0.09698:    1
##  Max.   : 782.0   Max.   : 582.0   Max.   : 694.0   -0.14677:    1
##                                                     (Other) :  218
##  kurtosis_picth_arm kurtosis_yaw_arm skewness_roll_arm skewness_pitch_arm
##           :13459             :13459           :13459           :13459
##  #DIV/0! :   56     #DIV/0! :    7   #DIV/0! :   55    #DIV/0! :   56
##  -0.00484:    1     0.55844 :    2   -0.00051:    1    -0.00184:    1
##  -0.02967:    1     0.65132 :    2   -0.00696:    1    -0.01185:    1
##  -0.10385:    1     -0.01548:    1   -0.04186:    1    -0.01247:    1
```

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##  -0.15381:    1     -0.01749:    1   -0.05049:    1    -0.02652:    1
##  (Other) :  218     (Other) :  265   (Other) :  219    (Other) :  218
##  skewness_yaw_arm  max_roll_arm    max_picth_arm      max_yaw_arm
##          :13459   Min.   :-73.10   Min.   :-173.00   Min.   : 6.00
##  #DIV/0! :    7   1st Qu.:  0.00   1st Qu.:  -3.00   1st Qu.:29.00
##  -1.62032:    2   Median :  4.80   Median :  18.95   Median :34.00
##  0.55053 :    2   Mean   : 11.49   Mean   :  32.83   Mean   :35.46
##  -0.00311:    1   3rd Qu.: 27.45   3rd Qu.:  93.90   3rd Qu.:41.00
##  -0.00562:    1   Max.   : 85.50   Max.   : 180.00   Max.   :65.00
##  (Other) :  265   NA's   :13459    NA's   :13459     NA's   :13459
##   min_roll_arm    min_pitch_arm      min_yaw_arm    amplitude_roll_arm
##  Min.   :-88.80   Min.   :-180.00   Min.   : 2.00   Min.   :  0.000
##  1st Qu.:-41.62   1st Qu.: -80.25   1st Qu.: 7.25   1st Qu.:  6.325
##  Median :-22.40   Median : -39.20   Median :12.00   Median : 28.305
##  Mean   :-20.67   Mean   : -37.60   Mean   :14.28   Mean   : 32.167
##  3rd Qu.:  0.00   3rd Qu.:   0.00   3rd Qu.:18.75   3rd Qu.: 50.680
##  Max.   : 66.40   Max.   : 152.00   Max.   :38.00   Max.   :119.500
##  NA's   :13459    NA's   :13459     NA's   :13459   NA's   :13459
##  amplitude_pitch_arm amplitude_yaw_arm roll_dumbbell     pitch_dumbbell
##  Min.   :  0.00      Min.   : 0.00     Min.   :-153.71   Min.   :-149.59
##  1st Qu.: 10.10      1st Qu.:13.00     1st Qu.: -18.80   1st Qu.: -40.16
##  Median : 53.95      Median :22.00     Median :  47.93   Median : -20.88
##  Mean   : 70.43      Mean   :21.17     Mean   :  23.64   Mean   : -10.63
##  3rd Qu.:120.42      3rd Qu.:29.00     3rd Qu.:  67.45   3rd Qu.:  17.56
##  Max.   :360.00      Max.   :52.00     Max.   : 153.55   Max.   : 149.40
##  NA's   :13459       NA's   :13459
##   yaw_dumbbell      kurtosis_roll_dumbbell kurtosis_picth_dumbbell
##  Min.   :-150.871          :13459                 :13459
##  1st Qu.: -77.643   #DIV/0!:    3          -0.5464:    2
##  Median :  -3.184   -0.2583:    2          -0.9334:    2
##  Mean   :   2.030   -0.3705:    2          -2.0851:    2
##  3rd Qu.:  80.630   -2.0851:    2          -2.0889:    2
##  Max.   : 154.754   -2.0889:    2          #DIV/0!:    2
##                     (Other):  267          (Other):  268
##  kurtosis_yaw_dumbbell skewness_roll_dumbbell skewness_pitch_dumbbell
##         :13459                :13459                 :13459
##  #DIV/0!:  278         -0.9324:    2          -0.2328:    2
##                        #DIV/0!:    2          0.1090 :    2
##                        1.0312 :    2          1.0326 :    2
##                        -0.0082:    1          -0.0053:    1
##                        -0.0096:    1          -0.0166:    1
##                        (Other):  270          (Other):  270
##  skewness_yaw_dumbbell max_roll_dumbbell max_picth_dumbbell
##         :13459         Min.   :-70.00    Min.   :-108.00
##  #DIV/0!:  278         1st Qu.:-27.82    1st Qu.: -67.60
##                        Median : 13.05    Median :  42.80
##                        Mean   : 12.59    Mean   :  32.82
##                        3rd Qu.: 50.45    3rd Qu.: 131.97
##                        Max.   :137.00    Max.   : 154.20
##                        NA's   :13459     NA's   :13459
```

```
##  max_yaw_dumbbell min_roll_dumbbell min_pitch_dumbbell min_yaw_dumbbell
##         :13459    Min.   :-149.60   Min.   :-147.00           :13459
##  -0.6   :   15    1st Qu.: -59.67   1st Qu.: -91.80    -0.6   :   15
##  -0.7   :   12    Median : -44.00   Median : -62.10    -0.7   :   12
##  -0.5   :   11    Mean   : -41.28   Mean   : -32.96    -0.5   :   11
##  -0.8   :   11    3rd Qu.: -26.95   3rd Qu.:  16.60    -0.8   :   11
##  0.0    :   11    Max.   :  73.20   Max.   : 116.70    0.0    :   11
##  (Other):  218    NA's   :13459     NA's   :13459      (Other):  218
##  amplitude_roll_dumbbell amplitude_pitch_dumbbell amplitude_yaw_dumbbell
##  Min.   :  0.00          Min.   :  0.00                   :13459
##  1st Qu.: 14.57          1st Qu.: 16.78           #DIV/0!:    3
##  Median : 33.66          Median : 41.59           0.00   :  275
##  Mean   : 53.87          Mean   : 65.78
##  3rd Qu.: 83.17          3rd Qu.:101.69
##  Max.   :256.48          Max.   :273.59
##  NA's   :13459           NA's   :13459
##  total_accel_dumbbell var_accel_dumbbell avg_roll_dumbbell
##  Min.   : 0.00        Min.   : 0.000     Min.   :-128.96
##  1st Qu.: 4.00        1st Qu.: 0.362     1st Qu.: -12.48
##  Median :10.00        Median : 0.937     Median :  48.63
##  Mean   :13.67        Mean   : 3.428     Mean   :  23.24
##  3rd Qu.:19.00        3rd Qu.: 3.157     3rd Qu.:  64.37
##  Max.   :58.00        Max.   :45.237     Max.   : 125.99
##                       NA's   :13459      NA's   :13459
##  stddev_roll_dumbbell var_roll_dumbbell  avg_pitch_dumbbell
##  Min.   :  0.000      Min.   :    0.00   Min.   :-70.46
##  1st Qu.:  4.577      1st Qu.:   20.95   1st Qu.:-43.24
##  Median : 11.866      Median :  140.80   Median :-20.90
##  Mean   : 20.429      Mean   :  998.10   Mean   :-13.67
##  3rd Qu.: 26.270      3rd Qu.:  690.12   3rd Qu.: 12.46
##  Max.   :123.778      Max.   :15321.01   Max.   : 94.28
##  NA's   :13459        NA's   :13459      NA's   :13459
##  stddev_pitch_dumbbell var_pitch_dumbbell avg_yaw_dumbbell
##  Min.   : 0.000         Min.   :   0.00    Min.   :-117.950
##  1st Qu.: 3.391         1st Qu.:  11.50    1st Qu.: -76.257
##  Median : 7.943         Median :  63.09    Median :  -2.530
##  Mean   :12.666         Mean   : 320.92    Mean   :   0.747
##  3rd Qu.:18.740         3rd Qu.: 351.19    3rd Qu.:  71.808
##  Max.   :62.881         Max.   :3953.97    Max.   : 134.905
##  NA's   :13459          NA's   :13459      NA's   :13459
##  stddev_yaw_dumbbell var_yaw_dumbbell   gyros_dumbbell_x
##  Min.   :  0.000     Min.   :    0.00   Min.   :-204.0000
##  1st Qu.:  3.866     1st Qu.:   14.95   1st Qu.:  -0.0300
##  Median : 10.170     Median :  103.43   Median :   0.1300
##  Mean   : 16.699     Mean   :  604.62   Mean   :   0.1556
##  3rd Qu.: 25.439     3rd Qu.:  647.15   3rd Qu.:   0.3500
##  Max.   :107.088     Max.   :11467.91   Max.   :   2.2200
##  NA's   :13459       NA's   :13459
##  gyros_dumbbell_y   gyros_dumbbell_z   accel_dumbbell_x  accel_dumbbell_y
##  Min.   :-2.10000   Min.   : -2.3800   Min.   :-419.00   Min.   :-182.00
```

```
##  1st Qu.:-0.14000   1st Qu.: -0.3100   1st Qu.: -50.00   1st Qu.:  -8.00
##  Median : 0.03000   Median : -0.1300   Median :  -8.00   Median :  41.00
##  Mean   : 0.04688   Mean   : -0.1215   Mean   : -28.21   Mean   :  52.55
##  3rd Qu.: 0.21000   3rd Qu.:  0.0300   3rd Qu.:  11.00   3rd Qu.: 110.00
##  Max.   :52.00000   Max.   :317.0000   Max.   : 235.00   Max.   : 315.00
##
##  accel_dumbbell_z  magnet_dumbbell_x magnet_dumbbell_y magnet_dumbbell_z
##  Min.   :-319.00   Min.   :-643.0    Min.   :-3600     Min.   :-262.00
##  1st Qu.:-141.00   1st Qu.:-535.0    1st Qu.:  232     1st Qu.: -45.00
##  Median :  -1.00   Median :-480.0    Median :  311     Median :  14.00
##  Mean   : -37.88   Mean   :-329.2    Mean   :  222     Mean   :  46.26
##  3rd Qu.:  38.00   3rd Qu.:-305.0    3rd Qu.:  390     3rd Qu.:  95.00
##  Max.   : 318.00   Max.   : 592.0    Max.   :  633     Max.   : 452.00
##
##   roll_forearm     pitch_forearm     yaw_forearm
##  Min.   :-180.00   Min.   :-72.50   Min.   :-180.00
##  1st Qu.:  -1.22   1st Qu.:  0.00   1st Qu.: -69.10
##  Median :  19.60   Median :  9.34   Median :   0.00
##  Mean   :  33.07   Mean   : 10.74   Mean   :  18.63
##  3rd Qu.: 140.00   3rd Qu.: 28.50   3rd Qu.: 110.00
##  Max.   : 180.00   Max.   : 89.80   Max.   : 180.00
##
##  kurtosis_roll_forearm kurtosis_picth_forearm kurtosis_yaw_forearm
##         :13459                :13459                 :13459
##  #DIV/0!:   55         #DIV/0!:   56          #DIV/0!:  278
##  -0.9169:    2         -0.0073:    1
##  -0.0227:    1         -0.0442:    1
##  -0.0359:    1         -0.0489:    1
##  -0.1363:    1         -0.0523:    1
##  (Other):  218         (Other):  218
##  skewness_roll_forearm skewness_pitch_forearm skewness_yaw_forearm
##         :13459                :13459                 :13459
##  #DIV/0!:   54         #DIV/0!:   56          #DIV/0!:  278
##  -0.1912:    2         0.0000 :    2
##  -0.4126:    2         -0.0113:    1
##  -0.0004:    1         -0.0131:    1
##  -0.0013:    1         -0.0405:    1
##  (Other):  218         (Other):  217
##  max_roll_forearm max_picth_forearm max_yaw_forearm min_roll_forearm
##  Min.   :-66.60   Min.   :-149.00          :13459   Min.   :-72.50
##  1st Qu.:  0.00   1st Qu.:   0.00   #DIV/0!:   55   1st Qu.: -5.75
##  Median : 27.65   Median : 120.50   -1.2   :   21   Median :  0.00
##  Mean   : 24.85   Mean   :  84.26   -1.3   :   19   Mean   : -0.02
##  3rd Qu.: 48.48   3rd Qu.: 175.00   -1.6   :   18   3rd Qu.: 12.80
##  Max.   : 89.80   Max.   : 180.00   -1.4   :   17   Max.   : 62.10
##  NA's   :13459    NA's   :13459      (Other):  148   NA's   :13459
##  min_pitch_forearm min_yaw_forearm amplitude_roll_forearm
##  Min.   :-180.00          :13459   Min.   :  0.000
##  1st Qu.:-176.00   #DIV/0!:   55   1st Qu.:  1.817
##  Median : -81.25   -1.2   :   21   Median : 20.570
```

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##  Mean   : -61.33   -1.3   :   19   Mean   : 24.870
##  3rd Qu.:   0.00   -1.6   :   18   3rd Qu.: 39.775
##  Max.   : 167.00   -1.4   :   17   Max.   :126.000
##  NA's   :13459     (Other):  148   NA's   :13459
##  amplitude_pitch_forearm amplitude_yaw_forearm total_accel_forearm
##  Min.   :  0.00                 :13459         Min.   :  0.00
##  1st Qu.:  2.00          #DIV/0!:   55         1st Qu.: 29.00
##  Median : 85.03          0.00   :  223         Median : 36.00
##  Mean   :145.59                                Mean   : 34.74
##  3rd Qu.:352.75                                3rd Qu.: 41.00
##  Max.   :360.00                                Max.   :108.00
##  NA's   :13459
##  var_accel_forearm avg_roll_forearm   stddev_roll_forearm
##  Min.   :  0.000   Min.   :-177.111   Min.   :  0.000
##  1st Qu.:  7.213   1st Qu.:  -2.834   1st Qu.:  0.512
##  Median : 22.957   Median :  13.696   Median :  8.646
##  Mean   : 35.711   Mean   :  34.272   Mean   : 41.198
##  3rd Qu.: 56.050   3rd Qu.: 114.358   3rd Qu.: 72.433
##  Max.   :158.816   Max.   : 177.256   Max.   :179.171
##  NA's   :13459     NA's   :13459      NA's   :13459
##  var_roll_forearm   avg_pitch_forearm stddev_pitch_forearm
##  Min.   :    0.00   Min.   :-68.17    Min.   : 0.000
##  1st Qu.:    0.26   1st Qu.:  0.00    1st Qu.: 0.532
##  Median :   74.76   Median : 12.26    Median : 6.058
##  Mean   : 5156.33   Mean   : 11.95    Mean   : 8.082
##  3rd Qu.: 5246.69   3rd Qu.: 28.55    3rd Qu.:12.801
##  Max.   :32102.24   Max.   : 72.09    Max.   :47.745
##  NA's   :13459      NA's   :13459     NA's   :13459
##  var_pitch_forearm  avg_yaw_forearm   stddev_yaw_forearm
##  Min.   :   0.000   Min.   :-155.06   Min.   :  0.000
##  1st Qu.:   0.283   1st Qu.: -31.21   1st Qu.:  0.629
##  Median :  36.700   Median :   0.00   Median : 24.844
##  Mean   : 138.165   Mean   :  16.39   Mean   : 47.244
##  3rd Qu.: 163.875   3rd Qu.:  85.93   3rd Qu.: 97.301
##  Max.   :2279.617   Max.   : 168.86   Max.   :170.470
##  NA's   :13459      NA's   :13459     NA's   :13459
##  var_yaw_forearm     gyros_forearm_x    gyros_forearm_y
##  Min.   :    0.000   Min.   :-22.0000   Min.   : -7.02000
##  1st Qu.:    0.397   1st Qu.: -0.2100   1st Qu.: -1.51000
##  Median :  617.283   Median :  0.0500   Median :  0.02000
##  Mean   : 4985.718   Mean   :  0.1619   Mean   :  0.06286
##  3rd Qu.: 9468.268   3rd Qu.:  0.5800   3rd Qu.:  1.62000
##  Max.   :29059.857   Max.   :  3.9700   Max.   :311.00000
##  NA's   :13459
##  gyros_forearm_z    accel_forearm_x   accel_forearm_y  accel_forearm_z
##  Min.   : -8.0900   Min.   :-498.00   Min.   :-595.0   Min.   :-446.00
##  1st Qu.: -0.1800   1st Qu.:-179.00   1st Qu.:  56.0   1st Qu.:-182.00
##  Median :  0.0800   Median : -58.00   Median : 201.0   Median : -38.00
##  Mean   :  0.1538   Mean   : -62.79   Mean   : 164.2   Mean   : -54.47
##  3rd Qu.:  0.4900   3rd Qu.:  74.00   3rd Qu.: 314.0   3rd Qu.:  27.00
```

```
##  Max.   :231.0000   Max.   : 477.00   Max.   : 923.0   Max.   : 291.00
##
##  magnet_forearm_x  magnet_forearm_y magnet_forearm_z classe
##  Min.   :-1280.0   Min.   :-896.0   Min.   :-973.0   A:3906
##  1st Qu.: -618.0   1st Qu.:   7.0   1st Qu.: 183.0   B:2658
##  Median : -377.0   Median : 591.0   Median : 509.0   C:2396
##  Mean   : -313.6   Mean   : 381.1   Mean   : 390.9   D:2252
##  3rd Qu.:  -75.0   3rd Qu.: 737.0   3rd Qu.: 651.0   E:2525
##  Max.   :  663.0   Max.   :1480.0   Max.   :1080.0
##
```

```
#columns with high amount of NA's is max_roll_belt, max_picth_belt, min_roll_belt, mi
n_pitch_belt, amplitude_roll_belt, amplitude_pitch_belt, var_total_accel_belt, avg_ro
ll_belt, stddev_roll_belt, var_roll_belt, avg_pitch_belt, stddev_pitch_belt, var_pitc
h_belt, avg_yaw_belt,  stddev_yaw_belt,    var_yaw_belt, var_accel_arm, avg_roll_arm,
stddev_roll_arm, var_roll_arm, avg_pitch_arm     stddev_pitch_arm, var_pitch_arm, avg
_yaw_arm, stddev_yaw_arm, var_yaw_arm, max_roll_arm,max_picth_arm,  max_yaw_arm, min_
roll_arm, min_pitch_arm,  min_yaw_arm, amplitude_roll_arm, amplitude_pitch_arm, ampli
tude_yaw_arm, max_roll_dumbbell, max_picth_dumbbell, min_roll_dumbbell, min_pitch_dum
bbell, amplitude_roll_dumbbell,  amplitude_pitch_dumbbell, var_accel_dumbbell, avg_ro
ll_dumbbell, stddev_roll_dumbbell, var_roll_dumbbell, avg_pitch_dumbbell, stddev_pitc
h_dumbbell, var_pitch_dumbbell, avg_yaw_dumbbell, stddev_yaw_dumbbell, var_yaw_dumbbe
ll, max_roll_forearm, max_picth_forearm, min_roll_forearm,  min_pitch_forearm, amplit
ude_roll_forearm, amplitude_pitch_forearm, var_accel_forearm,avg_roll_forearm ,stddev
_roll_forearm, var_roll_forearm, avg_pitch_forearm, stddev_pitch_forearm, var_pitch_f
orearm,  avg_yaw_forearm, stddev_yaw_forearm, var_yaw_forearm
```

```
library(dplyr)
```

```
## Warning: package 'dplyr' was built under R version 3.1.3
```

```
##
## Attaching package: 'dplyr'
##
## The following objects are masked from 'package:stats':
##
##     filter, lag
##
## The following objects are masked from 'package:base':
##
##     intersect, setdiff, setequal, union
```

```
training <- select(training, -c(max_roll_belt, max_picth_belt, min_roll_belt, min_pit
ch_belt, amplitude_roll_belt, amplitude_pitch_belt, var_total_accel_belt, avg_roll_be
lt, stddev_roll_belt, var_roll_belt, avg_pitch_belt, stddev_pitch_belt, var_pitch_bel
t, avg_yaw_belt,  stddev_yaw_belt,    var_yaw_belt, var_accel_arm, avg_roll_arm, stdd
ev_roll_arm, var_roll_arm, avg_pitch_arm, stddev_pitch_arm, var_pitch_arm, avg_yaw_ar
m, stddev_yaw_arm, var_yaw_arm, max_roll_arm,max_picth_arm,  max_yaw_arm, min_roll_ar
m, min_pitch_arm,  min_yaw_arm, amplitude_roll_arm, amplitude_pitch_arm, amplitude_ya
w_arm, max_roll_dumbbell, max_picth_dumbbell, min_roll_dumbbell, min_pitch_dumbbell,
amplitude_roll_dumbbell,  amplitude_pitch_dumbbell, var_accel_dumbbell, avg_roll_dumb
bell, stddev_roll_dumbbell, var_roll_dumbbell, avg_pitch_dumbbell, stddev_pitch_dumbb
ell, var_pitch_dumbbell, avg_yaw_dumbbell, stddev_yaw_dumbbell, var_yaw_dumbbell, max
_roll_forearm, max_picth_forearm, min_roll_forearm,  min_pitch_forearm, amplitude_rol
l_forearm, amplitude_pitch_forearm, var_accel_forearm,avg_roll_forearm ,stddev_roll_f
orearm, var_roll_forearm, avg_pitch_forearm, stddev_pitch_forearm, var_pitch_forearm,
avg_yaw_forearm, stddev_yaw_forearm, var_yaw_forearm))


dim(training)
```

```
## [1] 13737    93
```

```
#remove the first 7 columns that are identifiers and time stamps, etc....don't add va
lue to the model fit process.
training <- select(training, 8:93)

dim(training)
```

```
## [1] 13737    86
```

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

nearzero
```

```
##                            freqRatio percentUnique zeroVar   nzv
## roll_belt                   1.149109    8.03668923   FALSE FALSE
## pitch_belt                  1.083969   12.17150761   FALSE FALSE
## yaw_belt                    1.142857   12.95770547   FALSE FALSE
## total_accel_belt            1.062347    0.19654946   FALSE FALSE
## kurtosis_roll_belt       2243.166667    1.99461309   FALSE  TRUE
## kurtosis_picth_belt       560.791667    1.68886948   FALSE  TRUE
## kurtosis_yaw_belt          48.413669    0.01455922   FALSE  TRUE
## skewness_roll_belt       2691.800000    1.99461309   FALSE  TRUE
## skewness_roll_belt.1      560.791667    1.76166557   FALSE  TRUE
## skewness_yaw_belt          48.413669    0.01455922   FALSE  TRUE
## max_yaw_belt              611.772727    0.42949698   FALSE  TRUE
## min_yaw_belt              611.772727    0.42949698   FALSE  TRUE
```

```
## amplitude_yaw_belt        50.788679    0.02911844   FALSE  TRUE
## gyros_belt_x               1.036923    0.88083279   FALSE FALSE
## gyros_belt_y               1.135722    0.48773386   FALSE FALSE
## gyros_belt_z               1.066285    1.16473757   FALSE FALSE
## accel_belt_x               1.030249    1.13561913   FALSE FALSE
## accel_belt_y               1.138651    0.98274732   FALSE FALSE
## accel_belt_z               1.125418    2.09652763   FALSE FALSE
## magnet_belt_x              1.030888    2.15476450   FALSE FALSE
## magnet_belt_y              1.058568    2.08924802   FALSE FALSE
## magnet_belt_z              1.012121    3.15935066   FALSE FALSE
## roll_arm                  52.177778   17.43466550   FALSE FALSE
## pitch_arm                 93.960000   20.36106865   FALSE FALSE
## yaw_arm                   30.894737   19.24728835   FALSE FALSE
## total_accel_arm            1.038156    0.47317464   FALSE FALSE
## gyros_arm_x                1.000000    4.54975613   FALSE FALSE
## gyros_arm_y                1.391892    2.68617602   FALSE FALSE
## gyros_arm_z                1.087193    1.71070831   FALSE FALSE
## accel_arm_x                1.032787    5.57618112   FALSE FALSE
## accel_arm_y                1.148649    3.82179515   FALSE FALSE
## accel_arm_z                1.113636    5.60529956   FALSE FALSE
## magnet_arm_x               1.030303    9.60180534   FALSE FALSE
## magnet_arm_y               1.100000    6.24590522   FALSE FALSE
## magnet_arm_z               1.118421    9.09223266   FALSE FALSE
## kurtosis_roll_arm        240.339286    1.63063260   FALSE  TRUE
## kurtosis_picth_arm       240.339286    1.63063260   FALSE  TRUE
## kurtosis_yaw_arm        1922.714286    1.97277426   FALSE  TRUE
## skewness_roll_arm        244.709091    1.63791221   FALSE  TRUE
## skewness_pitch_arm       240.339286    1.63063260   FALSE  TRUE
## skewness_yaw_arm        1922.714286    1.97277426   FALSE  TRUE
## roll_dumbbell              1.052632   86.61279755   FALSE FALSE
## pitch_dumbbell             2.357895   84.31972046   FALSE FALSE
## yaw_dumbbell               1.000000   86.01586955   FALSE FALSE
## kurtosis_roll_dumbbell  4486.333333    1.98733348   FALSE  TRUE
## kurtosis_picth_dumbbell 6729.500000    1.99461309   FALSE  TRUE
## kurtosis_yaw_dumbbell     48.413669    0.01455922   FALSE  TRUE
## skewness_roll_dumbbell  6729.500000    2.00917231   FALSE  TRUE
## skewness_pitch_dumbbell 6729.500000    2.00917231   FALSE  TRUE
## skewness_yaw_dumbbell     48.413669    0.01455922   FALSE  TRUE
## max_yaw_dumbbell         897.266667    0.45861542   FALSE  TRUE
## min_yaw_dumbbell         897.266667    0.45861542   FALSE  TRUE
## amplitude_yaw_dumbbell    48.941818    0.02183883   FALSE  TRUE
## total_accel_dumbbell       1.118257    0.30574361   FALSE FALSE
## gyros_dumbbell_x           1.057831    1.72526753   FALSE FALSE
## gyros_dumbbell_y           1.312808    1.94365582   FALSE FALSE
## gyros_dumbbell_z           1.099010    1.43408313   FALSE FALSE
## accel_dumbbell_x           1.057522    2.97736041   FALSE FALSE
## accel_dumbbell_y           1.017964    3.29766325   FALSE FALSE
## accel_dumbbell_z           1.232258    2.90456432   FALSE FALSE
## magnet_dumbbell_x          1.160000    7.67998835   FALSE FALSE
## magnet_dumbbell_y          1.156250    6.01295771   FALSE FALSE
```

```
## magnet_dumbbell_z          1.142857    4.78998326   FALSE FALSE
## roll_forearm              12.600917   13.78030138   FALSE FALSE
## pitch_forearm             63.906977   18.90514668   FALSE FALSE
## yaw_forearm               15.010929   12.89218898   FALSE FALSE
## kurtosis_roll_forearm    244.709091    1.63063260   FALSE  TRUE
## kurtosis_picth_forearm   240.339286    1.63063260   FALSE  TRUE
## kurtosis_yaw_forearm      48.413669    0.01455922   FALSE  TRUE
## skewness_roll_forearm    249.240741    1.63063260   FALSE  TRUE
## skewness_pitch_forearm   240.339286    1.62335299   FALSE  TRUE
## skewness_yaw_forearm      48.413669    0.01455922   FALSE  TRUE
## max_yaw_forearm          244.709091    0.29846400   FALSE  TRUE
## min_yaw_forearm          244.709091    0.29846400   FALSE  TRUE
## amplitude_yaw_forearm     60.354260    0.02183883   FALSE  TRUE
## total_accel_forearm        1.130282    0.48773386   FALSE FALSE
## gyros_forearm_x            1.143275    2.07468880   FALSE FALSE
## gyros_forearm_y            1.089494    5.19036180   FALSE FALSE
## gyros_forearm_z            1.149068    2.09652763   FALSE FALSE
## accel_forearm_x            1.112903    5.67081604   FALSE FALSE
## accel_forearm_y            1.102941    7.12673801   FALSE FALSE
## accel_forearm_z            1.017699    4.02562423   FALSE FALSE
## magnet_forearm_x           1.086207   10.57727306   FALSE FALSE
## magnet_forearm_y           1.254237   13.29984713   FALSE FALSE
## magnet_forearm_z           1.146341   11.71289219   FALSE FALSE
## classe                     1.469526    0.03639805   FALSE FALSE
```

```
nearzerotrue <- subset(nearzero, nearzero$nzv == TRUE)

#will remove these variables as well since they don't add anything to the model fit.
rownames(nearzerotrue)
```

```
##  [1] "kurtosis_roll_belt"      "kurtosis_picth_belt"
##  [3] "kurtosis_yaw_belt"       "skewness_roll_belt"
##  [5] "skewness_roll_belt.1"    "skewness_yaw_belt"
##  [7] "max_yaw_belt"            "min_yaw_belt"
##  [9] "amplitude_yaw_belt"      "kurtosis_roll_arm"
## [11] "kurtosis_picth_arm"      "kurtosis_yaw_arm"
## [13] "skewness_roll_arm"       "skewness_pitch_arm"
## [15] "skewness_yaw_arm"        "kurtosis_roll_dumbbell"
## [17] "kurtosis_picth_dumbbell" "kurtosis_yaw_dumbbell"
## [19] "skewness_roll_dumbbell"  "skewness_pitch_dumbbell"
## [21] "skewness_yaw_dumbbell"   "max_yaw_dumbbell"
## [23] "min_yaw_dumbbell"        "amplitude_yaw_dumbbell"
## [25] "kurtosis_roll_forearm"   "kurtosis_picth_forearm"
## [27] "kurtosis_yaw_forearm"    "skewness_roll_forearm"
## [29] "skewness_pitch_forearm"  "skewness_yaw_forearm"
## [31] "max_yaw_forearm"         "min_yaw_forearm"
## [33] "amplitude_yaw_forearm"
```

```
nearzerotruenames <- (rownames(nearzerotrue))
training <- select(training, -c(kurtosis_roll_belt, kurtosis_picth_belt, kurtosis_yaw
_belt, skewness_roll_belt,skewness_roll_belt.1, skewness_yaw_belt, max_yaw_belt, min_
yaw_belt,  amplitude_yaw_belt, kurtosis_roll_arm, kurtosis_picth_arm, kurtosis_yaw_ar
m, skewness_roll_arm, skewness_pitch_arm, skewness_yaw_arm,  kurtosis_roll_dumbbell,
kurtosis_picth_dumbbell, kurtosis_yaw_dumbbell, skewness_roll_dumbbell, skewness_pitc
h_dumbbell, skewness_yaw_dumbbell,  max_yaw_dumbbell,  min_yaw_dumbbell, amplitude_ya
w_dumbbell, kurtosis_roll_forearm,   kurtosis_picth_forearm,  kurtosis_yaw_forearm, s
kewness_roll_forearm, skewness_pitch_forearm,  skewness_yaw_forearm,  max_yaw_forearm
, min_yaw_forearm, amplitude_yaw_forearm ))

dim(training)
```

```
## [1] 13737    53
```

```
mod1 <- train(classe~., method="rpart", data=training)
```

```
## Loading required package: rpart
```

```
## Warning: package 'rpart' was built under R version 3.1.3
```

```
print(mod1, digits=3)
```

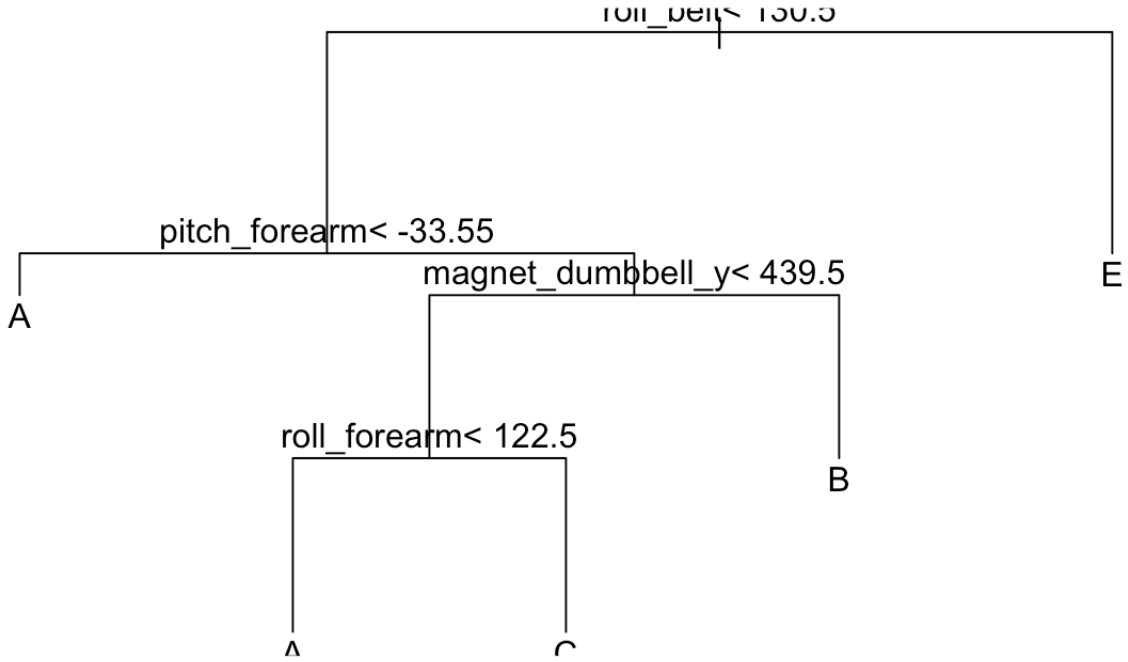
```
## CART
##
## 13737 samples
##    52 predictor
##     5 classes: 'A', 'B', 'C', 'D', 'E'
##
## No pre-processing
## Resampling: Bootstrapped (25 reps)
## Summary of sample sizes: 13737, 13737, 13737, 13737, 13737, 13737, ...
## Resampling results across tuning parameters:
##
##   cp      Accuracy  Kappa  Accuracy SD  Kappa SD
##   0.0353  0.523     0.384  0.0448       0.0719
##   0.0594  0.398     0.178  0.0549       0.0912
##   0.1171  0.351     0.102  0.0353       0.0519
##
## Accuracy was used to select the optimal model using  the largest value.
## The final value used for the model was cp = 0.0353.
```

```
print(mod1$finalModel, digits = 3)
```

```
## n= 13737
##
## node), split, n, loss, yval, (yprob)
##       * denotes terminal node
##
##  1) root 13737 9830 A (0.28 0.19 0.17 0.16 0.18)
##    2) roll_belt< 130 12568 8670 A (0.31 0.21 0.19 0.18 0.11)
##      4) pitch_forearm< -33.5 1117   11 A (0.99 0.0098 0 0 0) *
##      5) pitch_forearm>=-33.5 11451 8660 A (0.24 0.23 0.21 0.2 0.12)
##       10) magnet_dumbbell_y< 440 9681 6950 A (0.28 0.18 0.24 0.19 0.11)
##         20) roll_forearm< 122 6042 3600 A (0.4 0.18 0.19 0.17 0.06) *
##         21) roll_forearm>=122 3639 2450 C (0.078 0.18 0.33 0.23 0.18) *
##       11) magnet_dumbbell_y>=440 1770  862 B (0.034 0.51 0.039 0.22 0.19) *
##    3) roll_belt>=130 1169    9 E (0.0077 0 0 0 0.99) *
```

```
plot(mod1$finalModel)

text(mod1$finalModel, pretty = 0)
```



```
pred1 <- predict(mod1, newdata = testing)

print(confusionMatrix(pred1, testing$classe), digits = 3)
```

```
## Confusion Matrix and Statistics
##
##           Reference
## Prediction    A    B    C    D    E
##          A 1525  487  447  413  164
##          B   21  378   39  173  148
##          C  123  274  540  378  299
##          D    0    0    0    0    0
##          E    5    0    0    0  471
##
## Overall Statistics
##
##                Accuracy : 0.495
##                  95% CI : (0.482, 0.508)
##     No Information Rate : 0.284
##     P-Value [Acc > NIR] : <2e-16
##
##                   Kappa : 0.341
##  Mcnemar's Test P-Value : NA
##
## Statistics by Class:
##
##                      Class: A Class: B Class: C Class: D Class: E
## Sensitivity             0.911   0.3319   0.5263    0.000   0.4353
## Specificity             0.641   0.9197   0.7790    1.000   0.9990
## Pos Pred Value          0.502   0.4980   0.3346      NaN   0.9895
## Neg Pred Value          0.948   0.8515   0.8862    0.836   0.8870
## Prevalence              0.284   0.1935   0.1743    0.164   0.1839
## Detection Rate          0.259   0.0642   0.0918    0.000   0.0800
## Detection Prevalence    0.516   0.1290   0.2743    0.000   0.0809
## Balanced Accuracy       0.776   0.6258   0.6526    0.500   0.7171
```

```
#accuracy of a standard tree is 50.3%. Next we will look at a random forest method fr
om session 25.

set.seed(3)

# the processing time is significant for this large training set, so we can cut the d
ata in half for the random forest method and store into training1.

inTrain1 <- createDataPartition(y=training$classe, p=0.5, list=FALSE)
training1 <- training[inTrain1,]; training2 <- training[-inTrain1,]

#use the Random Forest from session 25 slide 9.....
mod2 <- train(classe~., method="rf", data=training1, trControl=trainControl(method="c
v"), number=3)
```

```
## Loading required package: randomForest
## randomForest 4.6-10
## Type rfNews() to see new features/changes/bug fixes.
##
## Attaching package: 'randomForest'
##
## The following object is masked from 'package:dplyr':
##
##     combine
##
## The following object is masked from 'package:ggplot2':
##
##     margin
```

```
print(mod2, digits=3)
```

```
## Random Forest
##
## 6869 samples
##   52 predictor
##    5 classes: 'A', 'B', 'C', 'D', 'E'
##
## No pre-processing
## Resampling: Cross-Validated (10 fold)
## Summary of sample sizes: 6183, 6183, 6182, 6182, 6183, 6180, ...
## Resampling results across tuning parameters:
##
##   mtry  Accuracy  Kappa  Accuracy SD  Kappa SD
##    2    0.982     0.978  0.00482      0.00611
##   27    0.984     0.980  0.00376      0.00476
##   52    0.980     0.974  0.00484      0.00612
##
## Accuracy was used to select the optimal model using  the largest value.
## The final value used for the model was mtry = 27.
```

```
print(mod2$finalModel, digits = 3)
```

```
##
## Call:
##  randomForest(x = x, y = y, mtry = param$mtry, number = 3)
##                Type of random forest: classification
##                      Number of trees: 500
## No. of variables tried at each split: 27
##
##         OOB estimate of  error rate: 1.56%
## Confusion matrix:
##      A    B    C    D    E class.error
## A 1944    7    1    0    1 0.004608295
## B   17 1298   12    2    0 0.023325809
## C    0   15 1174    9    0 0.020033389
## D    0    3   25 1097    1 0.025754885
## E    0    5    5    4 1249 0.011084719
```

```
#predict new data from the test data, 20 data points.
pred2 <- predict(mod2, newdata = testing)

print(confusionMatrix(pred2, testing$classe), digits = 3)
```

```
## Confusion Matrix and Statistics
##
##           Reference
## Prediction    A    B    C    D    E
##          A 1663   13    0    0    0
##          B   10 1115   21    0    1
##          C    1   11  999   24    2
##          D    0    0    6  936   13
##          E    0    0    0    4 1066
##
## Overall Statistics
##
##                Accuracy : 0.982
##                  95% CI : (0.978, 0.985)
##     No Information Rate : 0.284
##     P-Value [Acc > NIR] : <2e-16
##
##                   Kappa : 0.977
##  Mcnemar's Test P-Value : NA
##
## Statistics by Class:
##
##                      Class: A Class: B Class: C Class: D Class: E
## Sensitivity             0.993    0.979    0.974    0.971    0.985
## Specificity             0.997    0.993    0.992    0.996    0.999
## Pos Pred Value          0.992    0.972    0.963    0.980    0.996
## Neg Pred Value          0.997    0.995    0.994    0.994    0.997
## Prevalence              0.284    0.194    0.174    0.164    0.184
## Detection Rate          0.283    0.189    0.170    0.159    0.181
## Detection Prevalence    0.285    0.195    0.176    0.162    0.182
## Balanced Accuracy       0.995    0.986    0.983    0.984    0.992
```

The test data shows that a Random Forest will have a 98.4% accuracy. This is higher accuracy than the tree method.