Assessment : How to exercise efficiently ?

Background

Using devices such as Jawbone Up, Nike FuelBand, and Fitbit it is now possible to collect a large amount of data about personal activity relatively inexpensively. These type of devices are part of the quantified self movement - a group of enthusiasts who take measurements about themselves regularly to improve their health, to find patterns in their behavior, or because they are tech geeks. One thing that people regularly do is quantify how much of a particular activity they do, but they rarely quantify how well they do it. In this project, your goal will be to use data from accelerometers on the belt, forearm, arm, and dumbell of 6 participants. 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).

Library

```
library(caret)
```

```
## Warning: package 'caret' was built under R version 3.2.2
```

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

```
## Warning: package 'ggplot2' was built under R version 3.2.2
```

```
library(rpart)
library(rpart.plot)
```

```
## Warning: package 'rpart.plot' was built under R version 3.2.2
```

```
library(RColorBrewer)
library(rattle)
```

```
## Warning: package 'rattle' was built under R version 3.2.2
```

```
## Loading required package: RGtk2
```

```
## Warning: package 'RGtk2' was built under R version 3.2.2
```

```
## Rattle: A free graphical interface for data mining with R.
## Version 3.5.0 Copyright (c) 2006-2015 Togaware Pty Ltd.
## Type 'rattle()' to shake, rattle, and roll your data.
```

```r
library(randomForest)
```

```
## Warning: package 'randomForest' was built under R version 3.2.2

## randomForest 4.6-10
## Type rfNews() to see new features/changes/bug fixes.
```

Random Number Generation

Integer vector, containing the random number generator (RNG) state for random number generation in R

```r
set.seed(12345)
```

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.

Download both training dataset :-

```r
curdir <-getwd()
file.url<-'http://d396qusza40orc.cloudfront.net/predmachlearn/pml-training.csv'
download.file(file.url,destfile=paste(curdir,'/pml-training.csv',sep=""))

curdir <-getwd()
file.url<-'http://d396qusza40orc.cloudfront.net/predmachlearn/pml-testing.csv'
download.file(file.url,destfile=paste(curdir,'/pml-testing.csv',sep=""))
```

Load both dataset and change the missing value "#DIV/0!" to "NA" .

```r
training <-read.csv(paste(curdir,'/pml-training.csv',sep=""),na.strings=c("NA","#DIV/0!",""))
testing <-read.csv(paste(curdir,'/pml-testing.csv',sep=""), na.strings=c("NA","#DIV/0!", ""))
```

Delete column which has missing values.

```r
training<-training[,colSums(is.na(training)) == 0]
testing <-testing[,colSums(is.na(testing)) == 0]
```

Cheking the dimension of training and test dataset :-

```r
dim(training)
```

```
## [1] 19622    60
```

```r
dim(testing)
```

```
## [1] 20 60
```

Checking the columns which have all missing values

```r
training   <-training[,-c(1:7)]
testing <-testing[,-c(1:7)]
```

We remove 6 of the variables which is irrelevant like :-

a) user_name

b) raw_timestamp_part_1

c) raw_timestamp_part_2

d) cvtd_timestamp

e) new_window

f) num_window

which resides on the column 1-7.

```r
training   <-training[,-c(1:7)]
testing <-testing[,-c(1:7)]
```

Check again the dimension

```r
dim(training)
```

```
## [1] 19622    46
```

```r
dim(testing)
```

```
## [1] 20 46
```

Now we obtain the several rows to preview

```r
head(training)
```

```
##   accel_belt_x accel_belt_y accel_belt_z magnet_belt_x magnet_belt_y
## 1          -21            4           22            -3           599
## 2          -22            4           22            -7           608
## 3          -20            5           23            -2           600
## 4          -22            3           21            -6           604
## 5          -21            2           24            -6           600
## 6          -21            4           21             0           603
##   magnet_belt_z roll_arm pitch_arm yaw_arm total_accel_arm gyros_arm_x
## 1          -313     -128      22.5    -161              34        0.00
```

```
## 2         -311     -128      22.5    -161             34        0.02
## 3         -305     -128      22.5    -161             34        0.02
## 4         -310     -128      22.1    -161             34        0.02
## 5         -302     -128      22.1    -161             34        0.00
## 6         -312     -128      22.0    -161             34        0.02
##   gyros_arm_y gyros_arm_z accel_arm_x accel_arm_y accel_arm_z magnet_arm_x
## 1        0.00       -0.02        -288         109        -123         -368
## 2       -0.02       -0.02        -290         110        -125         -369
## 3       -0.02       -0.02        -289         110        -126         -368
## 4       -0.03        0.02        -289         111        -123         -372
## 5       -0.03        0.00        -289         111        -123         -374
## 6       -0.03        0.00        -289         111        -122         -369
##   magnet_arm_y magnet_arm_z roll_dumbbell pitch_dumbbell yaw_dumbbell
## 1          337          516      13.05217      -70.49400    -84.87394
## 2          337          513      13.13074      -70.63751    -84.71065
## 3          344          513      12.85075      -70.27812    -85.14078
## 4          344          512      13.43120      -70.39379    -84.87363
## 5          337          506      13.37872      -70.42856    -84.85306
## 6          342          513      13.38246      -70.81759    -84.46500
##   total_accel_dumbbell gyros_dumbbell_x gyros_dumbbell_y gyros_dumbbell_z
## 1                   37                0            -0.02             0.00
## 2                   37                0            -0.02             0.00
## 3                   37                0            -0.02             0.00
## 4                   37                0            -0.02            -0.02
## 5                   37                0            -0.02             0.00
## 6                   37                0            -0.02             0.00
##   accel_dumbbell_x accel_dumbbell_y accel_dumbbell_z magnet_dumbbell_x
## 1             -234               47             -271              -559
## 2             -233               47             -269              -555
## 3             -232               46             -270              -561
## 4             -232               48             -269              -552
## 5             -233               48             -270              -554
## 6             -234               48             -269              -558
##   magnet_dumbbell_y magnet_dumbbell_z roll_forearm pitch_forearm
## 1               293               -65         28.4         -63.9
## 2               296               -64         28.3         -63.9
## 3               298               -63         28.3         -63.9
## 4               303               -60         28.1         -63.9
## 5               292               -68         28.0         -63.9
## 6               294               -66         27.9         -63.9
##   yaw_forearm total_accel_forearm gyros_forearm_x gyros_forearm_y
## 1        -153                  36            0.03            0.00
## 2        -153                  36            0.02            0.00
## 3        -152                  36            0.03           -0.02
## 4        -152                  36            0.02           -0.02
## 5        -152                  36            0.02            0.00
## 6        -152                  36            0.02           -0.02
##   gyros_forearm_z accel_forearm_x accel_forearm_y accel_forearm_z
## 1           -0.02             192             203            -215
## 2           -0.02             192             203            -216
## 3            0.00             196             204            -213
## 4            0.00             189             206            -214
## 5           -0.02             189             206            -214
## 6           -0.03             193             203            -215
```

```
##   magnet_forearm_x magnet_forearm_y magnet_forearm_z classe
## 1              -17              654              476      A
## 2              -18              661              473      A
## 3              -18              658              469      A
## 4              -16              658              469      A
## 5              -17              655              473      A
## 6               -9              660              478      A
```

```r
head(testing)
```

```
##   accel_belt_x accel_belt_y accel_belt_z magnet_belt_x magnet_belt_y
## 1          -38           69         -179           -13           581
## 2          -13           11           39            43           636
## 3            1           -1           49            29           631
## 4           46           45         -156           169           608
## 5           -8            4           27            33           566
## 6          -11          -16           38            31           638
##   magnet_belt_z roll_arm pitch_arm yaw_arm total_accel_arm gyros_arm_x
## 1          -382     40.7    -27.80     178              10       -1.65
## 2          -309      0.0      0.00       0              38       -1.17
## 3          -312      0.0      0.00       0              44        2.10
## 4          -304   -109.0     55.00    -142              25        0.22
## 5          -418     76.1      2.76     102              29       -1.96
## 6          -291      0.0      0.00       0              14        0.02
##   gyros_arm_y gyros_arm_z accel_arm_x accel_arm_y accel_arm_z magnet_arm_x
## 1        0.48       -0.18          16          38          93         -326
## 2        0.85       -0.43        -290         215         -90         -325
## 3       -1.36        1.13        -341         245         -87         -264
## 4       -0.51        0.92        -238         -57           6         -173
## 5        0.79       -0.54        -197         200         -30         -170
## 6        0.05       -0.07         -26         130         -19          396
##   magnet_arm_y magnet_arm_z roll_dumbbell pitch_dumbbell yaw_dumbbell
## 1          385          481     -17.73748       24.96085    126.23596
## 2          447          434      54.47761      -53.69758    -75.51480
## 3          474          413      57.07031      -51.37303    -75.20287
## 4          257          633      43.10927      -30.04885   -103.32003
## 5          275          617    -101.38396      -53.43952    -14.19542
## 6          176          516      62.18750      -50.55595    -71.12063
##   total_accel_dumbbell gyros_dumbbell_x gyros_dumbbell_y gyros_dumbbell_z
## 1                    9             0.64             0.06            -0.61
## 2                   31             0.34             0.05            -0.71
## 3                   29             0.39             0.14            -0.34
## 4                   18             0.10            -0.02             0.05
## 5                    4             0.29            -0.47            -0.46
## 6                   29            -0.59             0.80             1.10
##   accel_dumbbell_x accel_dumbbell_y accel_dumbbell_z magnet_dumbbell_x
## 1               21              -15               81               523
## 2             -153              155             -205              -502
## 3             -141              155             -196              -506
## 4              -51               72             -148              -576
## 5              -18              -30               -5              -424
## 6             -138              166             -186              -543
##   magnet_dumbbell_y magnet_dumbbell_z roll_forearm pitch_forearm
## 1              -528               -56          141         49.30
```

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

In order to run cross-validation , the training dataset need to partition into 2 sets . We set the 1st partition for training dataset to 75% and test dataset to 25%. Training dataset contains 53 variables with 19622 obs and test dataset contains 53 variables with 20 obs.

This will do the randomize sub-sampling without replacement

```
chunks <- createDataPartition(y=training$classe, p=0.75, list=FALSE)
chunks_training <- training[chunks, ];
chunks_testing <- training[-chunks, ]
dim(chunks_training);
```

```
## [1] 14718    46
```

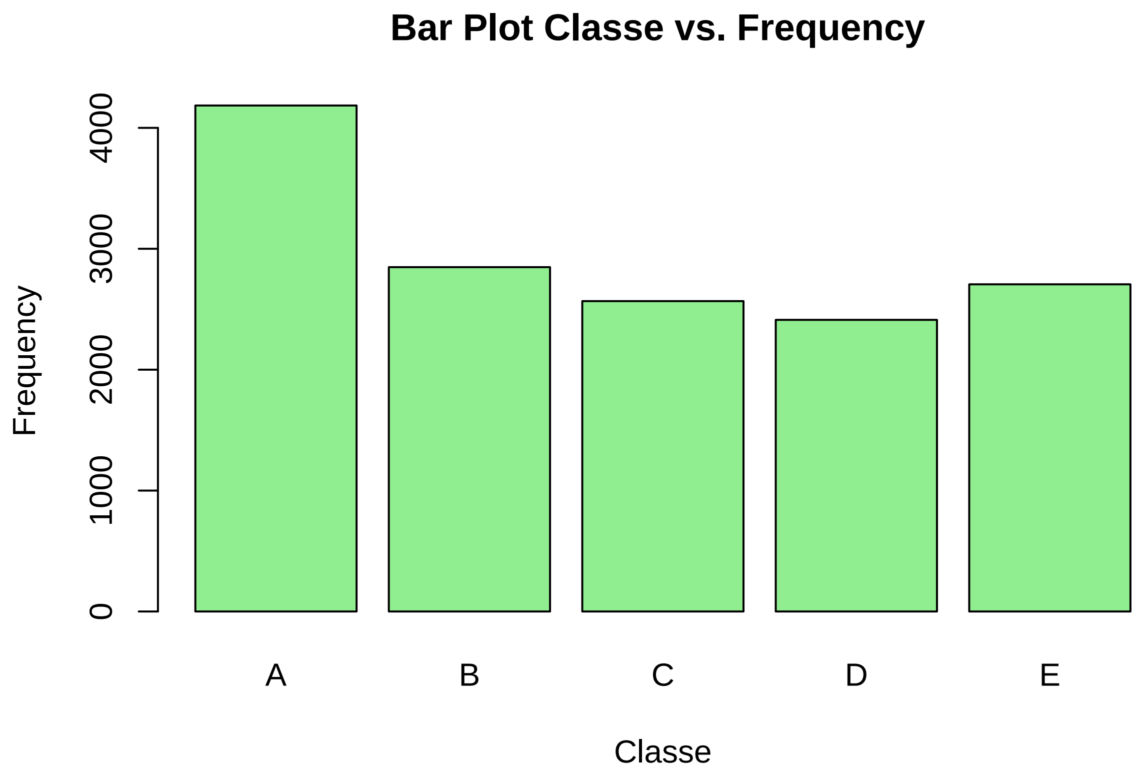
```
dim(chunks_testing);
```

```
## [1] 4904   46
```

Visualization

We try to plot into the histogram to see the trending frequency of each sub-training & test dataset by comparing with each other. The variable classe contains 5 levels which is A,B,C,D & E

```
plot(chunks_training$classe, col="lightgreen", main="Bar Plot Classe vs. Frequency ", xlab="Classe", yla
```



The graph above shows that A ~ 4000x occurrences is most frequent while D is the lest frequent ~ 2500x occurrences

Decision Tree

Decision Tree machine learning algorithm as a support tool that uses a tree-like graph or model of decisions and their possible consequences, including chance event outcomes, resource costs, and utility.

```
Fit_Model_1 <- rpart(classe ~ ., data=chunks_training, method="class")
```

Displays the (Complexity) cp table for fitted model .

```
printcp(Fit_Model_1)
```

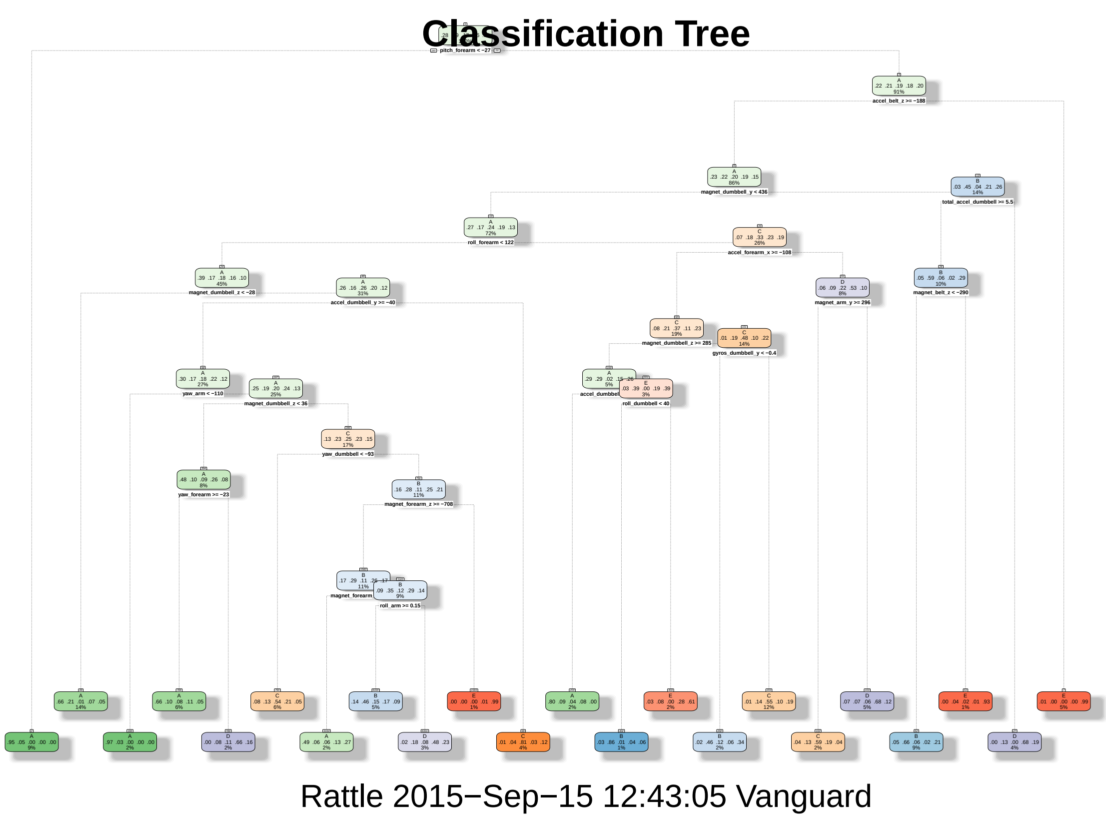
```
##
## Classification tree:
## rpart(formula = classe ~ ., data = chunks_training, method = "class")
##
## Variables actually used in tree construction:
##  [1] accel_belt_z        accel_dumbbell_y     accel_dumbbell_z
##  [4] accel_forearm_x     gyros_dumbbell_y     magnet_arm_y
##  [7] magnet_belt_z       magnet_dumbbell_y    magnet_dumbbell_z
## [10] magnet_forearm_x    magnet_forearm_z     pitch_forearm
## [13] roll_arm            roll_dumbbell        roll_forearm
```

```
## [16] total_accel_dumbbell yaw_arm              yaw_dumbbell
## [19] yaw_forearm
##
## Root node error: 10533/14718 = 0.71565
##
## n= 14718
##
##          CP nsplit rel error  xerror      xstd
## 1  0.062826      0   1.00000 1.00000 0.0051957
## 2  0.033134      4   0.74869 0.74983 0.0057435
## 3  0.031615      5   0.71556 0.72335 0.0057553
## 4  0.021172      6   0.68395 0.68546 0.0057579
## 5  0.017089      8   0.64160 0.62708 0.0057286
## 6  0.015190      9   0.62451 0.58815 0.0056864
## 7  0.013956     10   0.60932 0.57211 0.0056637
## 8  0.013909     11   0.59537 0.55255 0.0056316
## 9  0.013102     15   0.52027 0.52995 0.0055885
## 10 0.011266     17   0.49407 0.48941 0.0054946
## 11 0.010728     20   0.46027 0.47318 0.0054508
## 12 0.010000     21   0.44954 0.46596 0.0054301
```

To visualize the decision tree , we use this fancyRpartPlot command below :-

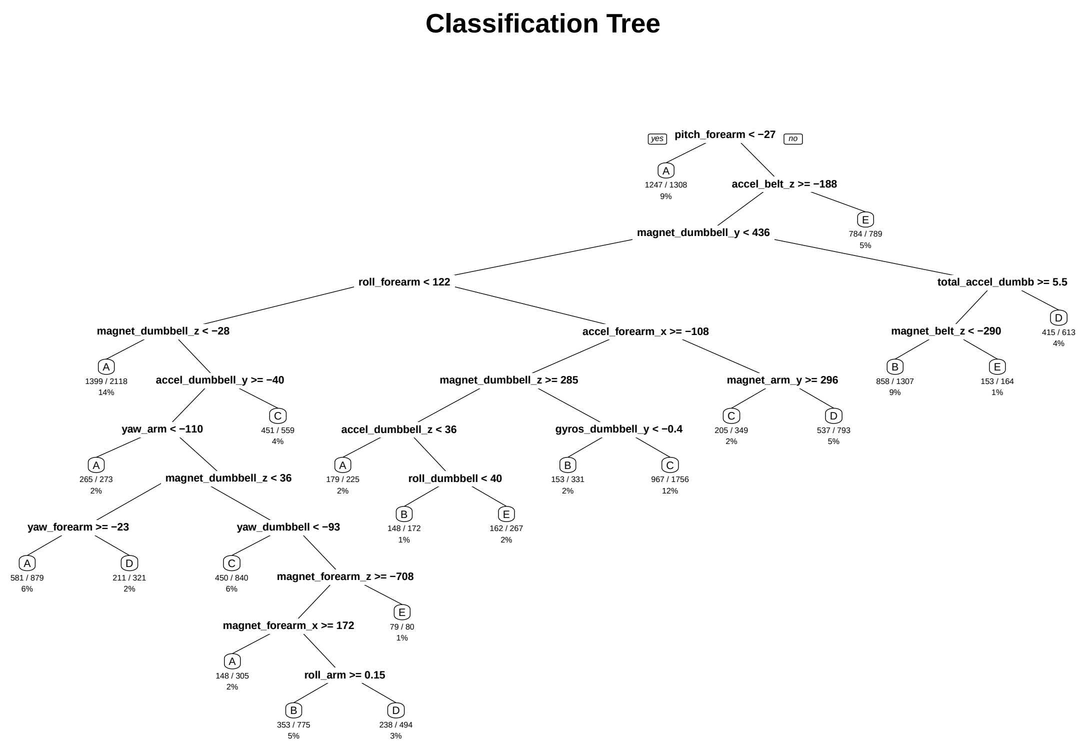
```r
fancyRpartPlot(Fit_Model_1,main="Classification Tree")
```

```
## Warning: labs do not fit even at cex 0.15, there may be some overplotting
```



Green nodes represent individuals classified by the tree as A, blue nodes are those classified as B and orange nodes are classified as C. The gradient is a visual representation of the three numbers in the middle of the nodes: bearing in mind that levels of a factor are by default in alphabetical order, the first of these three numbers is the proportion of individuals in that node that were actually classified as the first level, (A), in train_part ; the second number is the proportion that were actually classified as B, and the third the proportion that were C.

```
rpart.plot(Fit_Model_1,main="Classification Tree",extra=102, under=TRUE, faclen=0)
```



Now we predict the fit model for test dataset .

```
Prediction_Model1 <- predict(Fit_Model_1, chunks_testing, type = "class")
```

Confusion Matrix

Confusion matrix, also known as a contingency table or an error matrix , is a specific table layout that allows visualization of the performance of an algorithm, typically a supervised learning one (in unsupervised learning it is usually called a matching matrix). Each column of the matrix represents the instances in a predicted class while each row represents the instances in an actual class (or vice-versa).

```
confusionMatrix(Prediction_Model1, chunks_testing$classe)
```

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

```
##
##           Reference
## Prediction    A    B    C    D    E
##          A 1277  217   40  115   92
##          B   61  483   83   68  160
##          C   36  150  674  141  155
##          D   19   83   56  445  128
##          E    2   16    2   35  366
##
## Overall Statistics
##
##                Accuracy : 0.6617
##                  95% CI : (0.6483, 0.6749)
##     No Information Rate : 0.2845
##     P-Value [Acc > NIR] : < 2.2e-16
##
##                   Kappa : 0.5685
##  Mcnemar's Test P-Value : < 2.2e-16
##
## Statistics by Class:
##
##                      Class: A Class: B Class: C Class: D Class: E
## Sensitivity            0.9154  0.50896   0.7883  0.55348  0.40622
## Specificity            0.8678  0.90594   0.8810  0.93024  0.98626
## Pos Pred Value         0.7335  0.56491   0.5830  0.60876  0.86936
## Neg Pred Value         0.9627  0.88491   0.9517  0.91397  0.88066
## Prevalence             0.2845  0.19352   0.1743  0.16395  0.18373
## Detection Rate         0.2604  0.09849   0.1374  0.09074  0.07463
## Detection Prevalence   0.3550  0.17435   0.2357  0.14906  0.08585
## Balanced Accuracy      0.8916  0.70745   0.8346  0.74186  0.69624
```

Random Forest

Random forests are an ensemble learning method for classification, regression and other tasks, that operate by constructing a multitude of decision trees at training time and outputting the class that is the mode of the classes (classification) or mean prediction (regression) of the individual trees. Random forests correct for decision trees' habit of overfitting to their training set.

```
Fit_Model_2 <- randomForest(classe ~. , data=chunks_training)
```

Now we predict the fit model for test dataset .

```
Prediction_Model2 <- predict(Fit_Model_2, chunks_testing, type = "class")
```

Below is the confusion matrix of the test results

```
confusionMatrix(Prediction_Model2, chunks_testing$classe)
```

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

```
## Prediction    A    B    C    D    E
##          A 1394    5    0    0    0
##          B    1  939    5    0    0
##          C    0    5  850   11    1
##          D    0    0    0  790    4
##          E    0    0    0    3  896
##
## Overall Statistics
##
##                Accuracy : 0.9929
##                  95% CI : (0.9901, 0.995)
##     No Information Rate : 0.2845
##     P-Value [Acc > NIR] : < 2.2e-16
##
##                   Kappa : 0.991
##  Mcnemar's Test P-Value : NA
##
## Statistics by Class:
##
##                      Class: A Class: B Class: C Class: D Class: E
## Sensitivity            0.9993   0.9895   0.9942   0.9826   0.9945
## Specificity            0.9986   0.9985   0.9958   0.9990   0.9993
## Pos Pred Value         0.9964   0.9937   0.9804   0.9950   0.9967
## Neg Pred Value         0.9997   0.9975   0.9988   0.9966   0.9988
## Prevalence             0.2845   0.1935   0.1743   0.1639   0.1837
## Detection Rate         0.2843   0.1915   0.1733   0.1611   0.1827
## Detection Prevalence   0.2853   0.1927   0.1768   0.1619   0.1833
## Balanced Accuracy      0.9989   0.9940   0.9950   0.9908   0.9969
```

Conclusion

From the machine learning method above , the cross validation accuracy of the Decision Tree is ~ 66.17% and the Random Forest is ~ 99.3% which is better and the sample error rate rather small around ~ 0.07% .

```
Final_Prediction <- predict(Fit_Model_2, testing, type = "class")
```

Random Forests generally needs larger number of instances to work its randomization concept well and generalize to the novel data. In addition, in one way or another, random forests works with combination of some kind of soft linear boundaries at the decision surface

Prediction files generator for assignment submission code

```
pml_write_files = function(x){
  n = length(x)
  for(i in 1:n){
    filename = paste0("problem_id_",i,".txt")
    write.table(x[i],file=filename,quote=FALSE,row.names=FALSE,col.names=FALSE)
  }
}
```

```r
pml_write_files(Final_Prediction)
```

Reference

Velloso, E.; Bulling, A.; Gellersen, H.; Ugulino, W.; Fuks, H. Qualitative Activity Recognition of Weight Lifting Exercises. Proceedings of 4th International Conference in Cooperation with SIGCHI (Augmented Human '13) . Stuttgart, Germany: ACM SIGCHI, 2013. Read more: http://groupware.les.inf.puc-rio.br/har#ixzz3lj0hACeI