title: “MachineLearningProject” author: “Aaron Smth” date: “September 12, 2016” output: html_document
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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).

What you should submit

The goal of your project is to predict the manner in which they did the exercise. This is the “classe” variable in the training set. You may use any of the other variables to predict with. You should create a report describing how you built your model, how you used cross validation, what you think the expected out of sample error is, and why you made the choices you did. You will also use your prediction model to predict 20 different test cases.

Data Preperation

Note: Please see appendix for data exploration

```
#Set Seed
#set.seed(12345)
#Load packages
library(caret)
```

```
## Warning: package 'caret' was built under R version 3.2.5

## Loading required package: lattice

## Warning: package 'lattice' was built under R version 3.2.3

## Loading required package: ggplot2

## Warning: package 'ggplot2' was built under R version 3.2.3
```

```
library(randomForest)
```

```
## Warning: package 'randomForest' was built under R version 3.2.5

## 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
```

```r
#load data
TrainingData <- read.csv('pml-training.csv', stringsAsFactors = F, na.strings = "")
TestData <- read.csv('pml-testing.csv', stringsAsFactors = F, na.strings = "")

#clean data

#Remove first seven columns of data as they are not predictors of #form, these fields include record ID
TrainingData <- TrainingData[, -(1:7)]
TestData <- TestData[, -(1:7)]

#set classe as factor data type
TrainingData$classe <- as.factor(TrainingData$classe)

#remove fields with near zero variance as they will not be good predictors
nzv <- nearZeroVar(TrainingData)
TrainingData  <- TrainingData[-nzv]
nzv <- nearZeroVar(TestData)
TestData <- TestData[-nzv]

#remove fields with missing data
TrainingData <- TrainingData[colSums(is.na(TrainingData)) == 0]
TestData <- TestData[colSums(is.na(TestData)) == 0]

#Split training data into training and validation data subsets for cross validation
trainIndex <- createDataPartition(TrainingData$classe, list = F, p = 0.7)
TrainSubset <- TrainingData[trainIndex, ]
ValidationSubset <- TrainingData[- trainIndex, ]
```

Modelselection - training data

Begin with random forest model with the training data

```r
# Train random forest model
RFModel1 <- randomForest(classe ~ .,data = TrainSubset, mtry = 25,ntree = 1000,proximity = F)
print(RFModel1)
```

```
##
## Call:
##  randomForest(formula = classe ~ ., data = TrainSubset, mtry = 25,      ntree = 1000, proximity = F)
##                Type of random forest: classification
##                      Number of trees: 1000
## No. of variables tried at each split: 25
##
##         OOB estimate of  error rate: 0.75%
## Confusion matrix:
##      A    B    C    D    E class.error
## A 3901    3    0    0    2 0.001280082
## B   18 2630   10    0    0 0.010534236
## C    0   17 2371    7    1 0.010434057
## D    0    1   31 2217    3 0.015541741
```

```
## E    0    0    3    7 2515 0.003960396
```

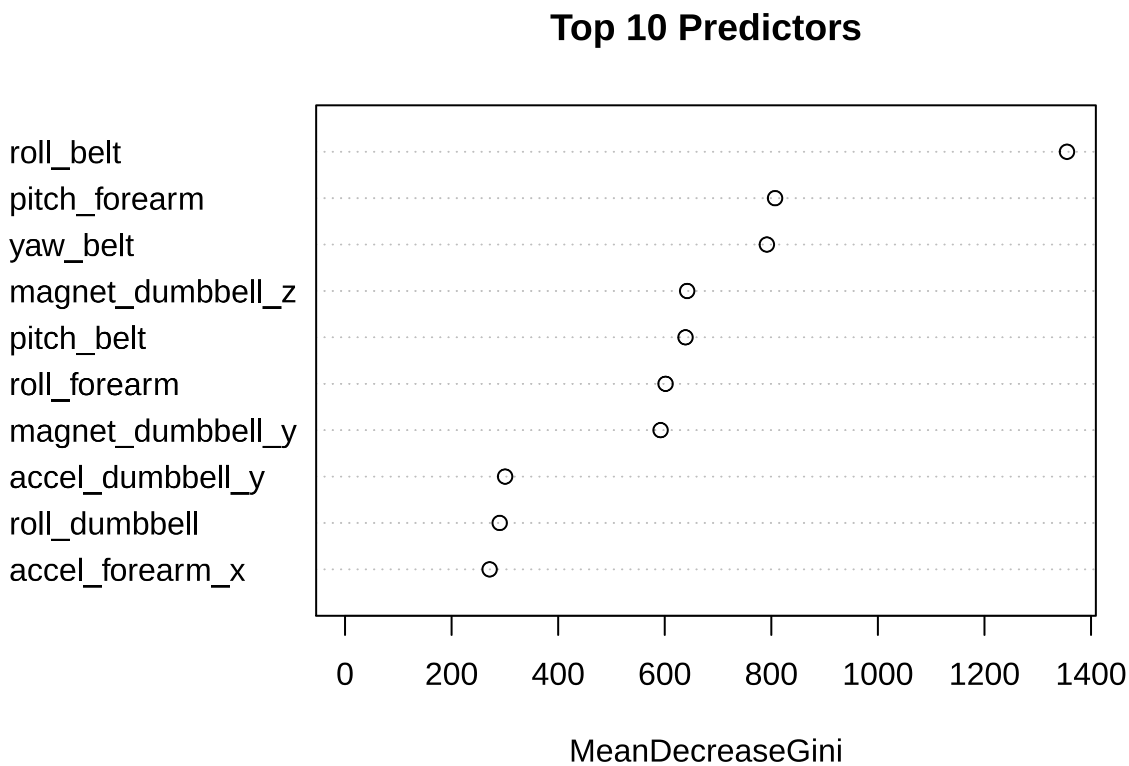
confusion matrix
Use validation data set to estimate out of sample error

```
RFPrediction1 <- predict(RFModel1, ValidationSubset)
ConMat <- confusionMatrix(ValidationSubset$classe, RFPrediction1)
print(ConMat)
```

```
## Confusion Matrix and Statistics
##
##           Reference
## Prediction    A    B    C    D    E
##          A 1673    1    0    0    0
##          B    6 1130    3    0    0
##          C    0    4 1018    4    0
##          D    0    0   12  952    0
##          E    0    1    4    2 1075
##
## Overall Statistics
##
##                Accuracy : 0.9937
##                  95% CI : (0.9913, 0.9956)
##     No Information Rate : 0.2853
##     P-Value [Acc > NIR] : < 2.2e-16
##
##                   Kappa : 0.992
##  Mcnemar's Test P-Value : NA
##
## Statistics by Class:
##
##                      Class: A Class: B Class: C Class: D Class: E
## Sensitivity            0.9964   0.9947   0.9817   0.9937   1.0000
## Specificity            0.9998   0.9981   0.9983   0.9976   0.9985
## Pos Pred Value         0.9994   0.9921   0.9922   0.9876   0.9935
## Neg Pred Value         0.9986   0.9987   0.9961   0.9988   1.0000
## Prevalence             0.2853   0.1930   0.1762   0.1628   0.1827
## Detection Rate         0.2843   0.1920   0.1730   0.1618   0.1827
## Detection Prevalence   0.2845   0.1935   0.1743   0.1638   0.1839
## Balanced Accuracy      0.9981   0.9964   0.9900   0.9957   0.9993
```

Plot variables by importance

```
# Top Ten most important predictors
varImpPlot(RFModel1, n.var = 10, main = "Top 10 Predictors")
```



Appendix

Data Exploration

```
#Review file variables
str(TrainingData)
```

```
## 'data.frame':    19622 obs. of  53 variables:
##  $ roll_belt           : num  1.41 1.41 1.42 1.48 1.48 1.45 1.42 1.42 1.43 1.45 ...
##  $ pitch_belt          : num  8.07 8.07 8.07 8.05 8.07 8.06 8.09 8.13 8.16 8.17 ...
##  $ yaw_belt            : num  -94.4 -94.4 -94.4 -94.4 -94.4 -94.4 -94.4 -94.4 -94.4 -94.4 ...
##  $ total_accel_belt    : int  3 3 3 3 3 3 3 3 3 3 ...
##  $ gyros_belt_x        : num  0 0.02 0 0.02 0.02 0.02 0.02 0.02 0.02 0.03 ...
##  $ gyros_belt_y        : num  0 0 0 0 0.02 0 0 0 0 0 ...
##  $ gyros_belt_z        : num  -0.02 -0.02 -0.02 -0.03 -0.02 -0.02 -0.02 -0.02 -0.02 0 ...
##  $ accel_belt_x        : int  -21 -22 -20 -22 -21 -21 -22 -22 -20 -21 ...
##  $ accel_belt_y        : int  4 4 5 3 2 4 3 4 2 4 ...
##  $ accel_belt_z        : int  22 22 23 21 24 21 21 21 24 22 ...
##  $ magnet_belt_x       : int  -3 -7 -2 -6 -6 0 -4 -2 1 -3 ...
##  $ magnet_belt_y       : int  599 608 600 604 600 603 599 603 602 609 ...
##  $ magnet_belt_z       : int  -313 -311 -305 -310 -302 -312 -311 -313 -312 -308 ...
##  $ roll_arm            : num  -128 -128 -128 -128 -128 -128 -128 -128 -128 -128 ...
##  $ pitch_arm           : num  22.5 22.5 22.5 22.1 22.1 22 21.9 21.8 21.7 21.6 ...
##  $ yaw_arm             : num  -161 -161 -161 -161 -161 -161 -161 -161 -161 -161 ...
##  $ total_accel_arm     : int  34 34 34 34 34 34 34 34 34 34 ...
##  $ gyros_arm_x         : num  0 0.02 0.02 0.02 0 0.02 0 0.02 0.02 0.02 ...
```

```
##  $ gyros_arm_y         : num  0 -0.02 -0.02 -0.03 -0.03 -0.03 -0.03 -0.02 -0.03 -0.03 ...
##  $ gyros_arm_z         : num  -0.02 -0.02 -0.02 0.02 0 0 0 0 -0.02 -0.02 ...
##  $ accel_arm_x         : int  -288 -290 -289 -289 -289 -289 -289 -289 -288 -288 ...
##  $ accel_arm_y         : int  109 110 110 111 111 111 111 111 109 110 ...
##  $ accel_arm_z         : int  -123 -125 -126 -123 -123 -122 -125 -124 -122 -124 ...
##  $ magnet_arm_x        : int  -368 -369 -368 -372 -374 -369 -373 -372 -369 -376 ...
##  $ magnet_arm_y        : int  337 337 344 344 337 342 336 338 341 334 ...
##  $ magnet_arm_z        : int  516 513 513 512 506 513 509 510 518 516 ...
##  $ 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 ...
##  $ total_accel_dumbbell: int  37 37 37 37 37 37 37 37 37 37 ...
##  $ gyros_dumbbell_x    : num  0 0 0 0 0 0 0 0 0 0 ...
##  $ gyros_dumbbell_y    : num  -0.02 -0.02 -0.02 -0.02 -0.02 -0.02 -0.02 -0.02 -0.02 -0.02 ...
##  $ gyros_dumbbell_z    : num  0 0 0 -0.02 0 0 0 0 0 0 ...
##  $ accel_dumbbell_x    : int  -234 -233 -232 -232 -233 -234 -232 -234 -232 -235 ...
##  $ accel_dumbbell_y    : int  47 47 46 48 48 48 47 46 47 48 ...
##  $ accel_dumbbell_z    : int  -271 -269 -270 -269 -270 -269 -270 -272 -269 -270 ...
##  $ magnet_dumbbell_x   : int  -559 -555 -561 -552 -554 -558 -551 -555 -549 -558 ...
##  $ magnet_dumbbell_y   : int  293 296 298 303 292 294 295 300 292 291 ...
##  $ magnet_dumbbell_z   : num  -65 -64 -63 -60 -68 -66 -70 -74 -65 -69 ...
##  $ roll_forearm        : num  28.4 28.3 28.3 28.1 28 27.9 27.9 27.8 27.7 27.7 ...
##  $ pitch_forearm       : num  -63.9 -63.9 -63.9 -63.9 -63.9 -63.9 -63.9 -63.8 -63.8 -63.8 ...
##  $ yaw_forearm         : num  -153 -153 -152 -152 -152 -152 -152 -152 -152 -152 ...
##  $ total_accel_forearm : int  36 36 36 36 36 36 36 36 36 36 ...
##  $ gyros_forearm_x     : num  0.03 0.02 0.03 0.02 0.02 0.02 0.02 0.02 0.03 0.02 ...
##  $ gyros_forearm_y     : num  0 0 -0.02 -0.02 0 -0.02 0 -0.02 0 0 ...
##  $ gyros_forearm_z     : num  -0.02 -0.02 0 0 -0.02 -0.03 -0.02 0 -0.02 -0.02 ...
##  $ accel_forearm_x     : int  192 192 196 189 189 193 195 193 193 190 ...
##  $ accel_forearm_y     : int  203 203 204 206 206 203 205 205 204 205 ...
##  $ accel_forearm_z     : int  -215 -216 -213 -214 -214 -215 -215 -213 -214 -215 ...
##  $ magnet_forearm_x    : int  -17 -18 -18 -16 -17 -9 -18 -9 -16 -22 ...
##  $ magnet_forearm_y    : num  654 661 658 658 655 660 659 660 653 656 ...
##  $ magnet_forearm_z    : num  476 473 469 469 473 478 470 474 476 473 ...
##  $ classe              : Factor w/ 5 levels "A","B","C","D",..: 1 1 1 1 1 1 1 1 1 1 ...
```

```r
summary(TrainingData)
```

```
##    roll_belt        pitch_belt          yaw_belt       total_accel_belt
##  Min.   :-28.90   Min.   :-55.8000   Min.   :-180.00   Min.   : 0.00   
##  1st Qu.:  1.10   1st Qu.:  1.7600   1st Qu.: -88.30   1st Qu.: 3.00   
##  Median :113.00   Median :  5.2800   Median : -13.00   Median :17.00   
##  Mean   : 64.41   Mean   :  0.3053   Mean   : -11.21   Mean   :11.31   
##  3rd Qu.:123.00   3rd Qu.: 14.9000   3rd Qu.:  12.90   3rd Qu.:18.00   
##  Max.   :162.00   Max.   : 60.3000   Max.   : 179.00   Max.   :29.00   
##   gyros_belt_x        gyros_belt_y       gyros_belt_z    
##  Min.   :-1.040000   Min.   :-0.64000   Min.   :-1.4600  
##  1st Qu.:-0.030000   1st Qu.: 0.00000   1st Qu.:-0.2000  
##  Median : 0.030000   Median : 0.02000   Median :-0.1000  
##  Mean   :-0.005592   Mean   : 0.03959   Mean   :-0.1305  
##  3rd Qu.: 0.110000   3rd Qu.: 0.11000   3rd Qu.:-0.0200  
##  Max.   : 2.220000   Max.   : 0.64000   Max.   : 1.6200  
##   accel_belt_x       accel_belt_y     accel_belt_z     magnet_belt_x  
##  Min.   :-120.000   Min.   :-69.00   Min.   :-275.00   Min.   :-52.0  
```

```
##  1st Qu.: -21.000   1st Qu.:  3.00   1st Qu.:-162.00   1st Qu.:  9.0  
##  Median : -15.000   Median : 35.00   Median :-152.00   Median : 35.0  
##  Mean   :  -5.595   Mean   : 30.15   Mean   : -72.59   Mean   : 55.6  
##  3rd Qu.:  -5.000   3rd Qu.: 61.00   3rd Qu.:  27.00   3rd Qu.: 59.0  
##  Max.   :  85.000   Max.   :164.00   Max.   : 105.00   Max.   :485.0  
##  magnet_belt_y   magnet_belt_z       roll_arm         pitch_arm      
##  Min.   :354.0   Min.   :-623.0   Min.   :-180.00   Min.   :-88.800  
##  1st Qu.:581.0   1st Qu.:-375.0   1st Qu.: -31.77   1st Qu.:-25.900  
##  Median :601.0   Median :-320.0   Median :   0.00   Median :  0.000  
##  Mean   :593.7   Mean   :-345.5   Mean   :  17.83   Mean   : -4.612  
##  3rd Qu.:610.0   3rd Qu.:-306.0   3rd Qu.:  77.30   3rd Qu.: 11.200  
##  Max.   :673.0   Max.   : 293.0   Max.   : 180.00   Max.   : 88.500  
##     yaw_arm          total_accel_arm  gyros_arm_x        gyros_arm_y     
##  Min.   :-180.0000   Min.   : 1.00   Min.   :-6.37000   Min.   :-3.4400  
##  1st Qu.: -43.1000   1st Qu.:17.00   1st Qu.:-1.33000   1st Qu.:-0.8000  
##  Median :   0.0000   Median :27.00   Median : 0.08000   Median :-0.2400  
##  Mean   :  -0.6188   Mean   :25.51   Mean   : 0.04277   Mean   :-0.2571  
##  3rd Qu.:  45.8750   3rd Qu.:33.00   3rd Qu.: 1.57000   3rd Qu.: 0.1400  
##  Max.   : 180.0000   Max.   :66.00   Max.   : 4.87000   Max.   : 2.8400  
##   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    roll_dumbbell    
##  Min.   :-584.0   Min.   :-392.0   Min.   :-597.0   Min.   :-153.71  
##  1st Qu.:-300.0   1st Qu.:  -9.0   1st Qu.: 131.2   1st Qu.: -18.49  
##  Median : 289.0   Median : 202.0   Median : 444.0   Median :  48.17  
##  Mean   : 191.7   Mean   : 156.6   Mean   : 306.5   Mean   :  23.84  
##  3rd Qu.: 637.0   3rd Qu.: 323.0   3rd Qu.: 545.0   3rd Qu.:  67.61  
##  Max.   : 782.0   Max.   : 583.0   Max.   : 694.0   Max.   : 153.55  
##  pitch_dumbbell     yaw_dumbbell      total_accel_dumbbell
##  Min.   :-149.59   Min.   :-150.871   Min.   : 0.00       
##  1st Qu.: -40.89   1st Qu.: -77.644   1st Qu.: 4.00       
##  Median : -20.96   Median :  -3.324   Median :10.00       
##  Mean   : -10.78   Mean   :   1.674   Mean   :13.72       
##  3rd Qu.:  17.50   3rd Qu.:  79.643   3rd Qu.:19.00       
##  Max.   : 149.40   Max.   : 154.952   Max.   :58.00       
##  gyros_dumbbell_x    gyros_dumbbell_y   gyros_dumbbell_z 
##  Min.   :-204.0000   Min.   :-2.10000   Min.   : -2.380  
##  1st Qu.:  -0.0300   1st Qu.:-0.14000   1st Qu.: -0.310  
##  Median :   0.1300   Median : 0.03000   Median : -0.130  
##  Mean   :   0.1611   Mean   : 0.04606   Mean   : -0.129  
##  3rd Qu.:   0.3500   3rd Qu.: 0.21000   3rd Qu.:  0.030  
##  Max.   :   2.2200   Max.   :52.00000   Max.   :317.000  
##  accel_dumbbell_x  accel_dumbbell_y  accel_dumbbell_z  magnet_dumbbell_x
##  Min.   :-419.00   Min.   :-189.00   Min.   :-334.00   Min.   :-643.0   
##  1st Qu.: -50.00   1st Qu.:  -8.00   1st Qu.:-142.00   1st Qu.:-535.0   
##  Median :  -8.00   Median :  41.50   Median :  -1.00   Median :-479.0   
##  Mean   : -28.62   Mean   :  52.63   Mean   : -38.32   Mean   :-328.5   
##  3rd Qu.:  11.00   3rd Qu.: 111.00   3rd Qu.:  38.00   3rd Qu.:-304.0   
##  Max.   : 235.00   Max.   : 315.00   Max.   : 318.00   Max.   : 592.0   
```

```
##  magnet_dumbbell_y magnet_dumbbell_z  roll_forearm       pitch_forearm
##  Min.   :-3600     Min.   :-262.00   Min.   :-180.0000   Min.   :-72.50
##  1st Qu.:  231     1st Qu.: -45.00   1st Qu.:  -0.7375   1st Qu.:  0.00
##  Median :  311     Median :  13.00   Median :  21.7000   Median :  9.24
##  Mean   :  221     Mean   :  46.05   Mean   :  33.8265   Mean   : 10.71
##  3rd Qu.:  390     3rd Qu.:  95.00   3rd Qu.: 140.0000   3rd Qu.: 28.40
##  Max.   :  633     Max.   : 452.00   Max.   : 180.0000   Max.   : 89.80
##   yaw_forearm      total_accel_forearm gyros_forearm_x
##  Min.   :-180.00   Min.   :  0.00      Min.   :-22.000
##  1st Qu.: -68.60   1st Qu.: 29.00      1st Qu.: -0.220
##  Median :   0.00   Median : 36.00      Median :  0.050
##  Mean   :  19.21   Mean   : 34.72      Mean   :  0.158
##  3rd Qu.: 110.00   3rd Qu.: 41.00      3rd Qu.:  0.560
##  Max.   : 180.00   Max.   :108.00      Max.   :  3.970
##  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
##  A:5580
##  B:3797
##  C:3422
##  D:3216
##  E:3607
##
```