Identifying Movement with HAR Devices

Executive Summary

In this study, we are looking at human activity recognition data to determine what type of activity is being performed based off the data values that are presented. We focus primarily on the *classe* variable, which is described by the following:

Classe: A-exactly according to specification, B-Elbows to the front, C-lifting halfway, D-lowering halfway, E-throwing hips to the front

If the data are categorized correctly, we will be able to tell whether the exercises are being performed properly or incorrectly.

Loading the Data

Before we get started, we first load the data and libraries into R.

```
library(caret)
```

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

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

```
library(ggplot2)
library(randomForest)
```

```
## 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
```

```
library(rpart)
library(rattle)
```

```
## Rattle: A free graphical interface for data mining with R.
## Version 4.1.0 Copyright (c) 2006-2015 Togaware Pty Ltd.
## Type 'rattle()' to shake, rattle, and roll your data.
```

```
set.seed(323)


urlTrain<-"https://d396qusza40orc.cloudfront.net/predmachlearn/pml-training.csv"
urlTest<-"https://d396qusza40orc.cloudfront.net/predmachlearn/pml-testing.csv"

training<-read.csv(urlTrain,header=TRUE,na.strings = c("NA", ""),sep=",")
testing<-read.csv(urlTest,header=TRUE,na.strings = c("NA", ""),sep=",")
```

Cleaning the Data

We look at the data:

```
str(training)
```

```
## 'data.frame':    19622 obs. of  160 variables:
##  $ X                       : int  1 2 3 4 5 6 7 8 9 10 ...
##  $ user_name               : Factor w/ 6 levels "adelmo","carlitos",..: 2 2 2 2 2 2 2 2 2 2 ...
##  $ raw_timestamp_part_1    : int  1323084231 1323084231 1323084231 1323084232 1323084232 1323084232 1
##  $ raw_timestamp_part_2    : int  788290 808298 820366 120339 196328 304277 368296 440390 484323 484
##  $ cvtd_timestamp          : Factor w/ 20 levels "02/12/2011 13:32",..: 9 9 9 9 9 9 9 9 9 9 ...
##  $ new_window              : Factor w/ 2 levels "no","yes": 1 1 1 1 1 1 1 1 1 1 ...
##  $ num_window              : int  11 11 11 12 12 12 12 12 12 12 ...
##  $ roll_belt               : num  1.41 1.41 1.42 1.48 1.48 1.45 1.42 1.42 1.43 1.45 ...
##  $ pitch_belt              : num  8.07 8.07 8.07 8.05 8.07 8.06 8.09 8.13 8.16 8.17 ...
##  $ yaw_belt                : num  -94.4 -94.4 -94.4 -94.4 -94.4 -94.4 -94.4 -94.4 -94.4 -94.4 ...
##  $ total_accel_belt        : int  3 3 3 3 3 3 3 3 3 3 ...
##  $ kurtosis_roll_belt      : Factor w/ 396 levels "-0.016850","-0.021024",..: NA NA NA NA NA NA NA NA
##  $ kurtosis_picth_belt     : Factor w/ 316 levels "-0.021887","-0.060755",..: NA NA NA NA NA NA NA NA
##  $ kurtosis_yaw_belt       : Factor w/ 1 level "#DIV/0!": NA NA NA NA NA NA NA NA NA NA ...
##  $ skewness_roll_belt      : Factor w/ 394 levels "-0.003095","-0.010002",..: NA NA NA NA NA NA NA NA
##  $ skewness_roll_belt.1    : Factor w/ 337 levels "-0.005928","-0.005960",..: NA NA NA NA NA NA NA NA
##  $ skewness_yaw_belt       : Factor w/ 1 level "#DIV/0!": NA NA NA NA NA NA NA NA NA NA ...
##  $ max_roll_belt           : num  NA NA NA NA NA NA NA NA NA NA ...
##  $ max_picth_belt          : int  NA NA NA NA NA NA NA NA NA NA ...
##  $ max_yaw_belt            : Factor w/ 67 levels "-0.1","-0.2",..: NA NA NA NA NA NA NA NA NA NA ...
##  $ min_roll_belt           : num  NA NA NA NA NA NA NA NA NA NA ...
##  $ min_pitch_belt          : int  NA NA NA NA NA NA NA NA NA NA ...
##  $ min_yaw_belt            : Factor w/ 67 levels "-0.1","-0.2",..: NA NA NA NA NA NA NA NA NA NA ...
##  $ amplitude_roll_belt     : num  NA NA NA NA NA NA NA NA NA NA ...
##  $ amplitude_pitch_belt    : int  NA NA NA NA NA NA NA NA NA NA ...
##  $ amplitude_yaw_belt      : Factor w/ 3 levels "#DIV/0!","0.00",..: NA NA NA NA NA NA NA NA NA NA .
##  $ var_total_accel_belt    : num  NA NA NA NA NA NA NA NA NA NA ...
##  $ avg_roll_belt           : num  NA NA NA NA NA NA NA NA NA NA ...
##  $ stddev_roll_belt        : num  NA NA NA NA NA NA NA NA NA NA ...
##  $ var_roll_belt           : num  NA NA NA NA NA NA NA NA NA NA ...
##  $ avg_pitch_belt          : num  NA NA NA NA NA NA NA NA NA NA ...
##  $ stddev_pitch_belt       : num  NA NA NA NA NA NA NA NA NA NA ...
##  $ var_pitch_belt          : num  NA NA NA NA NA NA NA NA NA NA ...
##  $ avg_yaw_belt            : num  NA NA NA NA NA NA NA NA NA NA ...
##  $ stddev_yaw_belt         : num  NA NA NA NA NA NA NA NA NA NA ...
##  $ var_yaw_belt            : num  NA NA NA NA NA NA NA NA NA NA ...
##  $ gyros_belt_x            : num  0 0.02 0 0.02 0.02 0.02 0.02 0.02 0.02 0.03 ...
##  $ gyros_belt_y            : num  0 0 0 0 0.02 0 0 0 0 0 ...
##  $ gyros_belt_z            : num  -0.02 -0.02 -0.02 -0.03 -0.02 -0.02 -0.02 -0.02 -0.02 0 ...
##  $ accel_belt_x            : int  -21 -22 -20 -22 -21 -21 -22 -22 -20 -21 ...
##  $ accel_belt_y            : int  4 4 5 3 2 4 3 4 2 4 ...
##  $ accel_belt_z            : int  22 22 23 21 24 21 21 21 24 22 ...
##  $ magnet_belt_x           : int  -3 -7 -2 -6 -6 0 -4 -2 1 -3 ...
##  $ magnet_belt_y           : int  599 608 600 604 600 603 599 603 602 609 ...
##  $ magnet_belt_z           : int  -313 -311 -305 -310 -302 -312 -311 -313 -312 -308 ...
##  $ roll_arm                : num  -128 -128 -128 -128 -128 -128 -128 -128 -128 -128 ...
##  $ pitch_arm               : num  22.5 22.5 22.5 22.1 22.1 22 21.9 21.8 21.7 21.6 ...
##  $ yaw_arm                 : num  -161 -161 -161 -161 -161 -161 -161 -161 -161 -161 ...
##  $ total_accel_arm         : int  34 34 34 34 34 34 34 34 34 34 ...
##  $ var_accel_arm           : num  NA NA NA NA NA NA NA NA NA NA ...
##  $ avg_roll_arm            : num  NA NA NA NA NA NA NA NA NA NA ...
```

```
##  $ stddev_roll_arm         : num  NA NA NA NA NA NA NA NA NA NA ...
##  $ var_roll_arm            : num  NA NA NA NA NA NA NA NA NA NA ...
##  $ avg_pitch_arm           : num  NA NA NA NA NA NA NA NA NA NA ...
##  $ stddev_pitch_arm        : num  NA NA NA NA NA NA NA NA NA NA ...
##  $ var_pitch_arm           : num  NA NA NA NA NA NA NA NA NA NA ...
##  $ avg_yaw_arm             : num  NA NA NA NA NA NA NA NA NA NA ...
##  $ stddev_yaw_arm          : num  NA NA NA NA NA NA NA NA NA NA ...
##  $ var_yaw_arm             : num  NA NA NA NA NA NA NA NA NA NA ...
##  $ gyros_arm_x             : num  0 0.02 0.02 0.02 0 0.02 0 0.02 0.02 0.02 ...
##  $ gyros_arm_y             : num  0 -0.02 -0.02 -0.03 -0.03 -0.03 -0.03 -0.02 -0.03 -0.03 ...
##  $ gyros_arm_z             : num  -0.02 -0.02 -0.02 0.02 0 0 0 0 -0.02 -0.02 ...
##  $ accel_arm_x             : int  -288 -290 -289 -289 -289 -289 -289 -289 -288 -288 ...
##  $ accel_arm_y             : int  109 110 110 111 111 111 111 111 109 110 ...
##  $ accel_arm_z             : int  -123 -125 -126 -123 -123 -122 -125 -124 -122 -124 ...
##  $ magnet_arm_x            : int  -368 -369 -368 -372 -374 -369 -373 -372 -369 -376 ...
##  $ magnet_arm_y            : int  337 337 344 344 337 342 336 338 341 334 ...
##  $ magnet_arm_z            : int  516 513 513 512 506 513 509 510 518 516 ...
##  $ kurtosis_roll_arm       : Factor w/ 329 levels "-0.02438","-0.04190",..: NA NA NA NA NA NA NA NA I
##  $ kurtosis_picth_arm      : Factor w/ 327 levels "-0.00484","-0.01311",..: NA NA NA NA NA NA NA NA I
##  $ kurtosis_yaw_arm        : Factor w/ 394 levels "-0.01548","-0.01749",..: NA NA NA NA NA NA NA NA I
##  $ skewness_roll_arm       : Factor w/ 330 levels "-0.00051","-0.00696",..: NA NA NA NA NA NA NA NA I
##  $ skewness_pitch_arm      : Factor w/ 327 levels "-0.00184","-0.01185",..: NA NA NA NA NA NA NA NA I
##  $ skewness_yaw_arm        : Factor w/ 394 levels "-0.00311","-0.00562",..: NA NA NA NA NA NA NA NA I
##  $ max_roll_arm            : num  NA NA NA NA NA NA NA NA NA NA ...
##  $ max_picth_arm           : num  NA NA NA NA NA NA NA NA NA NA ...
##  $ max_yaw_arm             : int  NA NA NA NA NA NA NA NA NA NA ...
##  $ min_roll_arm            : num  NA NA NA NA NA NA NA NA NA NA ...
##  $ min_pitch_arm           : num  NA NA NA NA NA NA NA NA NA NA ...
##  $ min_yaw_arm             : int  NA NA NA NA NA NA NA NA NA NA ...
##  $ amplitude_roll_arm      : num  NA NA NA NA NA NA NA NA NA NA ...
##  $ amplitude_pitch_arm     : num  NA NA NA NA NA NA NA NA NA NA ...
##  $ amplitude_yaw_arm       : int  NA NA NA NA NA NA NA NA NA NA ...
##  $ roll_dumbbell           : num  13.1 13.1 12.9 13.4 13.4 ...
##  $ pitch_dumbbell          : num  -70.5 -70.6 -70.3 -70.4 -70.4 ...
##  $ yaw_dumbbell            : num  -84.9 -84.7 -85.1 -84.9 -84.9 ...
##  $ kurtosis_roll_dumbbell  : Factor w/ 397 levels "-0.0035","-0.0073",..: NA NA NA NA NA NA NA NA NA
##  $ kurtosis_picth_dumbbell : Factor w/ 400 levels "-0.0163","-0.0233",..: NA NA NA NA NA NA NA NA NA
##  $ kurtosis_yaw_dumbbell   : Factor w/ 1 level "#DIV/0!": NA NA NA NA NA NA NA NA NA NA ...
##  $ skewness_roll_dumbbell  : Factor w/ 400 levels "-0.0082","-0.0096",..: NA NA NA NA NA NA NA NA NA
##  $ skewness_pitch_dumbbell : Factor w/ 401 levels "-0.0053","-0.0084",..: NA NA NA NA NA NA NA NA NA
##  $ skewness_yaw_dumbbell   : Factor w/ 1 level "#DIV/0!": NA NA NA NA NA NA NA NA NA NA ...
##  $ max_roll_dumbbell       : num  NA NA NA NA NA NA NA NA NA NA ...
##  $ max_picth_dumbbell      : num  NA NA NA NA NA NA NA NA NA NA ...
##  $ max_yaw_dumbbell        : Factor w/ 72 levels "-0.1","-0.2",..: NA NA NA NA NA NA NA NA NA NA ...
##  $ min_roll_dumbbell       : num  NA NA NA NA NA NA NA NA NA NA ...
##  $ min_pitch_dumbbell      : num  NA NA NA NA NA NA NA NA NA NA ...
##  $ min_yaw_dumbbell        : Factor w/ 72 levels "-0.1","-0.2",..: NA NA NA NA NA NA NA NA NA NA ...
##  $ amplitude_roll_dumbbell : num  NA NA NA NA NA NA NA NA NA NA ...
##   [list output truncated]
```

We see that the training set has 19622 observations of 160 variables. It's also notable that many of the variables have mostly NA's.

In order to clean up our data set, we remove the variables with more than 95% NA's. We also remove columns 1 through 7 which do not represent recorded output from the human activity measurement devices.

```r
#Remove columns with more than 95% NA's
trainData <- training[, colSums(is.na(training)) < 0.05*19622]
testData <- testing[, colSums(is.na(testing)) < 0.05*20]

#Remove columns 1:7 which do not represent output data
trainData<-trainData[,-c(1:7)]
testData<-testData[,-c(1:7)]
head(trainData)
```

```
##   roll_belt pitch_belt yaw_belt total_accel_belt gyros_belt_x gyros_belt_y
## 1      1.41       8.07    -94.4                3         0.00         0.00
## 2      1.41       8.07    -94.4                3         0.02         0.00
## 3      1.42       8.07    -94.4                3         0.00         0.00
## 4      1.48       8.05    -94.4                3         0.02         0.00
## 5      1.48       8.07    -94.4                3         0.02         0.02
## 6      1.45       8.06    -94.4                3         0.02         0.00
##   gyros_belt_z accel_belt_x accel_belt_y accel_belt_z magnet_belt_x
## 1        -0.02          -21            4           22            -3
## 2        -0.02          -22            4           22            -7
## 3        -0.02          -20            5           23            -2
## 4        -0.03          -22            3           21            -6
## 5        -0.02          -21            2           24            -6
## 6        -0.02          -21            4           21             0
##   magnet_belt_y magnet_belt_z roll_arm pitch_arm yaw_arm total_accel_arm
## 1           599          -313     -128      22.5    -161              34
## 2           608          -311     -128      22.5    -161              34
## 3           600          -305     -128      22.5    -161              34
## 4           604          -310     -128      22.1    -161              34
## 5           600          -302     -128      22.1    -161              34
## 6           603          -312     -128      22.0    -161              34
##   gyros_arm_x gyros_arm_y gyros_arm_z accel_arm_x accel_arm_y accel_arm_z
## 1        0.00        0.00       -0.02        -288         109        -123
## 2        0.02       -0.02       -0.02        -290         110        -125
## 3        0.02       -0.02       -0.02        -289         110        -126
## 4        0.02       -0.03        0.02        -289         111        -123
## 5        0.00       -0.03        0.00        -289         111        -123
## 6        0.02       -0.03        0.00        -289         111        -122
##   magnet_arm_x magnet_arm_y magnet_arm_z roll_dumbbell pitch_dumbbell
## 1         -368          337          516      13.05217      -70.49400
## 2         -369          337          513      13.13074      -70.63751
## 3         -368          344          513      12.85075      -70.27812
## 4         -372          344          512      13.43120      -70.39379
## 5         -374          337          506      13.37872      -70.42856
## 6         -369          342          513      13.38246      -70.81759
##   yaw_dumbbell total_accel_dumbbell gyros_dumbbell_x gyros_dumbbell_y
## 1    -84.87394                   37                0            -0.02
## 2    -84.71065                   37                0            -0.02
## 3    -85.14078                   37                0            -0.02
## 4    -84.87363                   37                0            -0.02
## 5    -84.85306                   37                0            -0.02
## 6    -84.46500                   37                0            -0.02
##   gyros_dumbbell_z accel_dumbbell_x accel_dumbbell_y accel_dumbbell_z
## 1             0.00             -234               47             -271
## 2             0.00             -233               47             -269
```

```
## 3             0.00             -232               46             -270
## 4            -0.02             -232               48             -269
## 5             0.00             -233               48             -270
## 6             0.00             -234               48             -269
##   magnet_dumbbell_x magnet_dumbbell_y magnet_dumbbell_z roll_forearm
## 1              -559               293               -65         28.4
## 2              -555               296               -64         28.3
## 3              -561               298               -63         28.3
## 4              -552               303               -60         28.1
## 5              -554               292               -68         28.0
## 6              -558               294               -66         27.9
##   pitch_forearm yaw_forearm total_accel_forearm gyros_forearm_x
## 1         -63.9        -153                  36            0.03
## 2         -63.9        -153                  36            0.02
## 3         -63.9        -152                  36            0.03
## 4         -63.9        -152                  36            0.02
## 5         -63.9        -152                  36            0.02
## 6         -63.9        -152                  36            0.02
##   gyros_forearm_y gyros_forearm_z accel_forearm_x accel_forearm_y
## 1            0.00           -0.02             192             203
## 2            0.00           -0.02             192             203
## 3           -0.02            0.00             196             204
## 4           -0.02            0.00             189             206
## 5            0.00           -0.02             189             206
## 6           -0.02           -0.03             193             203
##   accel_forearm_z magnet_forearm_x magnet_forearm_y magnet_forearm_z
## 1            -215              -17              654              476
## 2            -216              -18              661              473
## 3            -213              -18              658              469
## 4            -214              -16              658              469
## 5            -214              -17              655              473
## 6            -215               -9              660              478
##   classe
## 1      A
## 2      A
## 3      A
## 4      A
## 5      A
## 6      A
```

Partitioning the Data and Fitting a Model

Now that we have a cleaned data set, we can apply our machine learning algorithms. We partition the *trainData* data frame into 70% training and 30% validation set.

```
inTrain<-createDataPartition(trainData$classe,p=0.7,list=FALSE)
train1<- trainData[inTrain,]
validation<-trainData[-inTrain,]
```

Next, comes choosing the models. We will look at two models

Predicting with Random Forests

We first try predicting with the random forests model, which is often the most accurate.

```
modRF <- randomForest(classe ~. , data=train1)
predRF<-predict(modRF,validation)
confusionMatrix(predRF,validation$classe)$overall
```

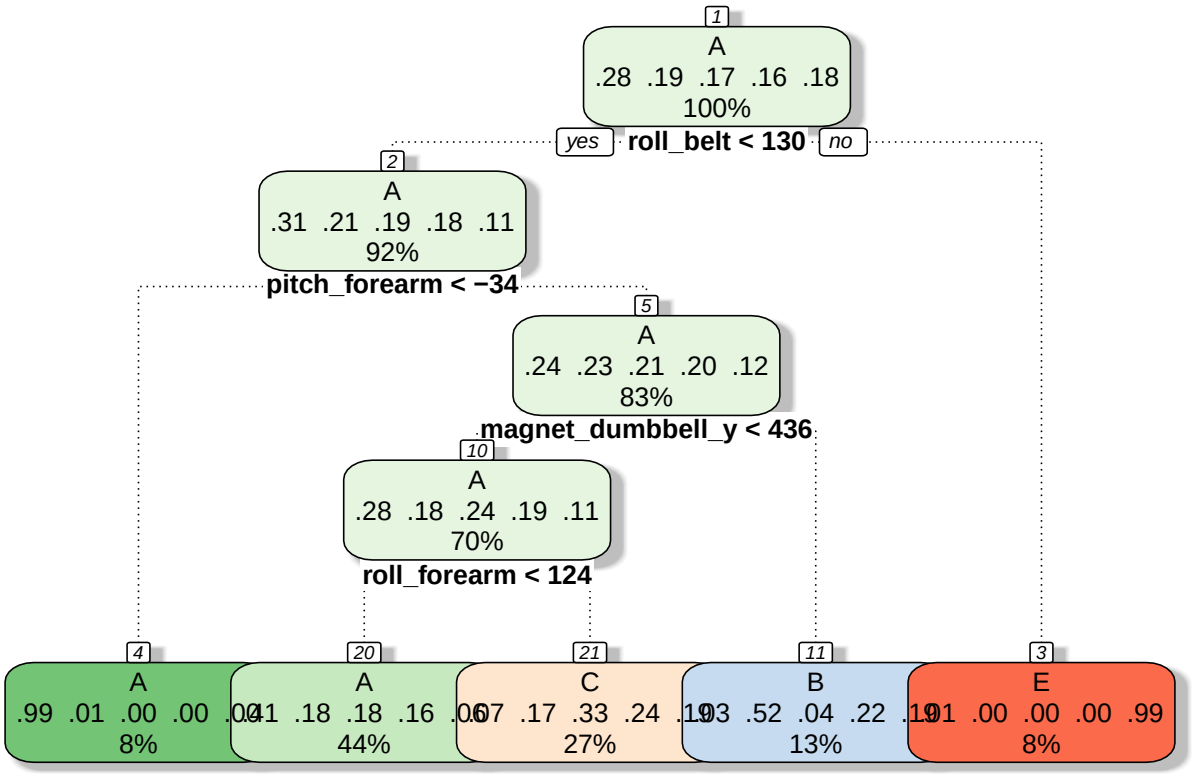
```
##       Accuracy          Kappa  AccuracyLower  AccuracyUpper   AccuracyNull
##      0.9954121      0.9941963      0.9933318      0.9969744      0.2844520
## AccuracyPValue  McnemarPValue
##      0.0000000            NaN
```

Through this model, we obtain 99.49% accuracy. Highly accurate. We try one more model to compare.

Predicting with an Rpart Decision Tree

Next we use recursive partitioning and present the data in a decision tree.

```
modRPart<-train(classe~.,method="rpart", data=train1)
fancyRpartPlot(modRPart$finalModel, cex=0.8)
```



We take our model for the training set and fit it to the validation set.

```
predRPart<-predict(modRPart,validation)
confusionMatrix(predRPart,validation$classe)$overall
```

```
##       Accuracy          Kappa  AccuracyLower  AccuracyUpper   AccuracyNull
```

```
##   4.842821e-01   3.252506e-01   4.714394e-01   4.971404e-01   2.844520e-01
## AccuracyPValue  McnemarPValue
##  2.036236e-229            NaN
```

Here we see only 49.91% accuracy. Our random forest model was the best fit so we will apply it to the test set.

Conclusions

We fit our random forest model to the test set to see how it applies to an unseen data set.

```
predTest<-predict(modRF,testData)
print(predTest)
```

```
##  1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20
##  B  A  B  A  A  E  D  B  A  A  B  C  B  A  E  E  A  B  B  B
## Levels: A B C D E
```

We have printed our predictions for all 20 observations in the test set. Because we have an accuracy of 99.49% (and thus an out of sample error of 0.51%) with our model, we expect that all 20 should be correct. This is shown to be the case by entering these results into the prediction quiz.