Predicting method of exercise

Exploratory analysis

First we load the data:

```
library(caret)
```

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

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

```
training <- read.csv("pml-training.csv")
testing <- read.csv("pml-testing.csv")
head(training)
```

```
##   X user_name raw_timestamp_part_1 raw_timestamp_part_2   cvtd_timestamp
## 1 1  carlitos           1323084231               788290 05/12/2011 11:23
## 2 2  carlitos           1323084231               808298 05/12/2011 11:23
## 3 3  carlitos           1323084231               820366 05/12/2011 11:23
## 4 4  carlitos           1323084232               120339 05/12/2011 11:23
## 5 5  carlitos           1323084232               196328 05/12/2011 11:23
## 6 6  carlitos           1323084232               304277 05/12/2011 11:23
##   new_window num_window roll_belt pitch_belt yaw_belt total_accel_belt
## 1         no         11      1.41       8.07    -94.4                3
## 2         no         11      1.41       8.07    -94.4                3
## 3         no         11      1.42       8.07    -94.4                3
## 4         no         12      1.48       8.05    -94.4                3
## 5         no         12      1.48       8.07    -94.4                3
## 6         no         12      1.45       8.06    -94.4                3
##   kurtosis_roll_belt kurtosis_picth_belt kurtosis_yaw_belt skewness_roll_belt
## 1
## 2
## 3
## 4
## 5
## 6
##   skewness_roll_belt.1 skewness_yaw_belt max_roll_belt max_picth_belt
## 1                                                   NA             NA
## 2                                                   NA             NA
## 3                                                   NA             NA
## 4                                                   NA             NA
## 5                                                   NA             NA
## 6                                                   NA             NA
##   max_yaw_belt min_roll_belt min_pitch_belt min_yaw_belt amplitude_roll_belt
## 1                        NA             NA                                NA
## 2                        NA             NA                                NA
## 3                        NA             NA                                NA
## 4                        NA             NA                                NA
## 5                        NA             NA                                NA
## 6                        NA             NA                                NA
##   amplitude_pitch_belt amplitude_yaw_belt var_total_accel_belt avg_roll_belt
## 1                   NA                                     NA            NA
## 2                   NA                                     NA            NA
## 3                   NA                                     NA            NA
## 4                   NA                                     NA            NA
## 5                   NA                                     NA            NA
## 6                   NA                                     NA            NA
##   stddev_roll_belt var_roll_belt avg_pitch_belt stddev_pitch_belt
## 1               NA            NA             NA                NA
## 2               NA            NA             NA                NA
## 3               NA            NA             NA                NA
## 4               NA            NA             NA                NA
## 5               NA            NA             NA                NA
## 6               NA            NA             NA                NA
##   var_pitch_belt avg_yaw_belt stddev_yaw_belt var_yaw_belt gyros_belt_x
## 1             NA           NA              NA           NA         0.00
## 2             NA           NA              NA           NA         0.02
## 3             NA           NA              NA           NA         0.00
```

```
## 4             NA           NA              NA           NA         0.02
## 5             NA           NA              NA           NA         0.02
## 6             NA           NA              NA           NA         0.02
##   gyros_belt_y gyros_belt_z accel_belt_x accel_belt_y accel_belt_z
## 1         0.00        -0.02          -21            4           22
## 2         0.00        -0.02          -22            4           22
## 3         0.00        -0.02          -20            5           23
## 4         0.00        -0.03          -22            3           21
## 5         0.02        -0.02          -21            2           24
## 6         0.00        -0.02          -21            4           21
##   magnet_belt_x magnet_belt_y magnet_belt_z roll_arm pitch_arm yaw_arm
## 1            -3           599          -313     -128      22.5    -161
## 2            -7           608          -311     -128      22.5    -161
## 3            -2           600          -305     -128      22.5    -161
## 4            -6           604          -310     -128      22.1    -161
## 5            -6           600          -302     -128      22.1    -161
## 6             0           603          -312     -128      22.0    -161
##   total_accel_arm var_accel_arm avg_roll_arm stddev_roll_arm var_roll_arm
## 1              34            NA           NA              NA           NA
## 2              34            NA           NA              NA           NA
## 3              34            NA           NA              NA           NA
## 4              34            NA           NA              NA           NA
## 5              34            NA           NA              NA           NA
## 6              34            NA           NA              NA           NA
##   avg_pitch_arm stddev_pitch_arm var_pitch_arm avg_yaw_arm stddev_yaw_arm
## 1            NA               NA            NA          NA             NA
## 2            NA               NA            NA          NA             NA
## 3            NA               NA            NA          NA             NA
## 4            NA               NA            NA          NA             NA
## 5            NA               NA            NA          NA             NA
## 6            NA               NA            NA          NA             NA
##   var_yaw_arm gyros_arm_x gyros_arm_y gyros_arm_z accel_arm_x accel_arm_y
## 1          NA        0.00        0.00       -0.02        -288         109
## 2          NA        0.02       -0.02       -0.02        -290         110
## 3          NA        0.02       -0.02       -0.02        -289         110
## 4          NA        0.02       -0.03        0.02        -289         111
## 5          NA        0.00       -0.03        0.00        -289         111
## 6          NA        0.02       -0.03        0.00        -289         111
##   accel_arm_z magnet_arm_x magnet_arm_y magnet_arm_z kurtosis_roll_arm
## 1        -123         -368          337          516
## 2        -125         -369          337          513
## 3        -126         -368          344          513
## 4        -123         -372          344          512
## 5        -123         -374          337          506
## 6        -122         -369          342          513
##   kurtosis_picth_arm kurtosis_yaw_arm skewness_roll_arm skewness_pitch_arm
## 1
## 2
## 3
## 4
## 5
## 6
##   skewness_yaw_arm max_roll_arm max_picth_arm max_yaw_arm min_roll_arm
## 1                           NA            NA          NA           NA
```

```
## 2                           NA            NA           NA            NA
## 3                           NA            NA           NA            NA
## 4                           NA            NA           NA            NA
## 5                           NA            NA           NA            NA
## 6                           NA            NA           NA            NA
##   min_pitch_arm min_yaw_arm amplitude_roll_arm amplitude_pitch_arm
## 1            NA          NA                 NA                  NA
## 2            NA          NA                 NA                  NA
## 3            NA          NA                 NA                  NA
## 4            NA          NA                 NA                  NA
## 5            NA          NA                 NA                  NA
## 6            NA          NA                 NA                  NA
##   amplitude_yaw_arm roll_dumbbell pitch_dumbbell yaw_dumbbell
## 1                NA      13.05217      -70.49400    -84.87394
## 2                NA      13.13074      -70.63751    -84.71065
## 3                NA      12.85075      -70.27812    -85.14078
## 4                NA      13.43120      -70.39379    -84.87363
## 5                NA      13.37872      -70.42856    -84.85306
## 6                NA      13.38246      -70.81759    -84.46500
##   kurtosis_roll_dumbbell kurtosis_picth_dumbbell kurtosis_yaw_dumbbell
## 1
## 2
## 3
## 4
## 5
## 6
##   skewness_roll_dumbbell skewness_pitch_dumbbell skewness_yaw_dumbbell
## 1
## 2
## 3
## 4
## 5
## 6
##   max_roll_dumbbell max_picth_dumbbell max_yaw_dumbbell min_roll_dumbbell
## 1                NA                 NA                                NA
## 2                NA                 NA                                NA
## 3                NA                 NA                                NA
## 4                NA                 NA                                NA
## 5                NA                 NA                                NA
## 6                NA                 NA                                NA
##   min_pitch_dumbbell min_yaw_dumbbell amplitude_roll_dumbbell
## 1                 NA                                      NA
## 2                 NA                                      NA
## 3                 NA                                      NA
## 4                 NA                                      NA
## 5                 NA                                      NA
## 6                 NA                                      NA
##   amplitude_pitch_dumbbell amplitude_yaw_dumbbell total_accel_dumbbell
## 1                       NA                                         37
## 2                       NA                                         37
## 3                       NA                                         37
## 4                       NA                                         37
## 5                       NA                                         37
## 6                       NA                                         37
```

```
##   var_accel_dumbbell avg_roll_dumbbell stddev_roll_dumbbell var_roll_dumbbell
## 1                 NA                NA                   NA                NA
## 2                 NA                NA                   NA                NA
## 3                 NA                NA                   NA                NA
## 4                 NA                NA                   NA                NA
## 5                 NA                NA                   NA                NA
## 6                 NA                NA                   NA                NA
##   avg_pitch_dumbbell stddev_pitch_dumbbell var_pitch_dumbbell avg_yaw_dumbbell
## 1                 NA                    NA                 NA               NA
## 2                 NA                    NA                 NA               NA
## 3                 NA                    NA                 NA               NA
## 4                 NA                    NA                 NA               NA
## 5                 NA                    NA                 NA               NA
## 6                 NA                    NA                 NA               NA
##   stddev_yaw_dumbbell var_yaw_dumbbell gyros_dumbbell_x gyros_dumbbell_y
## 1                  NA                NA                0            -0.02
## 2                  NA                NA                0            -0.02
## 3                  NA                NA                0            -0.02
## 4                  NA                NA                0            -0.02
## 5                  NA                NA                0            -0.02
## 6                  NA                NA                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 kurtosis_roll_forearm kurtosis_picth_forearm
## 1         -63.9        -153
## 2         -63.9        -153
## 3         -63.9        -152
## 4         -63.9        -152
## 5         -63.9        -152
## 6         -63.9        -152
##   kurtosis_yaw_forearm skewness_roll_forearm skewness_pitch_forearm
## 1
## 2
## 3
## 4
## 5
## 6
##   skewness_yaw_forearm max_roll_forearm max_picth_forearm max_yaw_forearm
## 1                                   NA                NA
## 2                                   NA                NA
## 3                                   NA                NA
## 4                                   NA                NA
```

```
## 5                                    NA                NA
## 6                                    NA                NA
##   min_roll_forearm min_pitch_forearm min_yaw_forearm amplitude_roll_forearm
## 1               NA                NA                                    NA
## 2               NA                NA                                    NA
## 3               NA                NA                                    NA
## 4               NA                NA                                    NA
## 5               NA                NA                                    NA
## 6               NA                NA                                    NA
##   amplitude_pitch_forearm amplitude_yaw_forearm total_accel_forearm
## 1                      NA                                       36
## 2                      NA                                       36
## 3                      NA                                       36
## 4                      NA                                       36
## 5                      NA                                       36
## 6                      NA                                       36
##   var_accel_forearm avg_roll_forearm stddev_roll_forearm var_roll_forearm
## 1                NA                NA                   NA               NA
## 2                NA                NA                   NA               NA
## 3                NA                NA                   NA               NA
## 4                NA                NA                   NA               NA
## 5                NA                NA                   NA               NA
## 6                NA                NA                   NA               NA
##   avg_pitch_forearm stddev_pitch_forearm var_pitch_forearm avg_yaw_forearm
## 1                NA                   NA                NA              NA
## 2                NA                   NA                NA              NA
## 3                NA                   NA                NA              NA
## 4                NA                   NA                NA              NA
## 5                NA                   NA                NA              NA
## 6                NA                   NA                NA              NA
##   stddev_yaw_forearm var_yaw_forearm gyros_forearm_x gyros_forearm_y
## 1                 NA              NA            0.03            0.00
## 2                 NA              NA            0.02            0.00
## 3                 NA              NA            0.03           -0.02
## 4                 NA              NA            0.02           -0.02
## 5                 NA              NA            0.02            0.00
## 6                 NA              NA            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
```

Remove columns with not a lot of data:

```
training <- training[, colSums(is.na(training)) < 19000 & colSums(training != '') > 1900
0]
training <- training[-c(1:6)] # exclude categorical variables
head(training)
```

```
##   num_window roll_belt pitch_belt yaw_belt total_accel_belt gyros_belt_x
## 1         11      1.41       8.07    -94.4                3         0.00
## 2         11      1.41       8.07    -94.4                3         0.02
## 3         11      1.42       8.07    -94.4                3         0.00
## 4         12      1.48       8.05    -94.4                3         0.02
## 5         12      1.48       8.07    -94.4                3         0.02
## 6         12      1.45       8.06    -94.4                3         0.02
##   gyros_belt_y gyros_belt_z accel_belt_x accel_belt_y accel_belt_z
## 1         0.00        -0.02          -21            4           22
## 2         0.00        -0.02          -22            4           22
## 3         0.00        -0.02          -20            5           23
## 4         0.00        -0.03          -22            3           21
## 5         0.02        -0.02          -21            2           24
## 6         0.00        -0.02          -21            4           21
##   magnet_belt_x magnet_belt_y magnet_belt_z roll_arm pitch_arm yaw_arm
## 1            -3           599          -313     -128      22.5    -161
## 2            -7           608          -311     -128      22.5    -161
## 3            -2           600          -305     -128      22.5    -161
## 4            -6           604          -310     -128      22.1    -161
## 5            -6           600          -302     -128      22.1    -161
## 6             0           603          -312     -128      22.0    -161
##   total_accel_arm gyros_arm_x gyros_arm_y gyros_arm_z accel_arm_x accel_arm_y
## 1              34        0.00        0.00       -0.02        -288         109
## 2              34        0.02       -0.02       -0.02        -290         110
## 3              34        0.02       -0.02       -0.02        -289         110
## 4              34        0.02       -0.03        0.02        -289         111
## 5              34        0.00       -0.03        0.00        -289         111
## 6              34        0.02       -0.03        0.00        -289         111
##   accel_arm_z magnet_arm_x magnet_arm_y magnet_arm_z roll_dumbbell
## 1        -123         -368          337          516      13.05217
## 2        -125         -369          337          513      13.13074
## 3        -126         -368          344          513      12.85075
## 4        -123         -372          344          512      13.43120
## 5        -123         -374          337          506      13.37872
## 6        -122         -369          342          513      13.38246
##   pitch_dumbbell yaw_dumbbell total_accel_dumbbell gyros_dumbbell_x
## 1      -70.49400    -84.87394                   37                0
## 2      -70.63751    -84.71065                   37                0
## 3      -70.27812    -85.14078                   37                0
## 4      -70.39379    -84.87363                   37                0
## 5      -70.42856    -84.85306                   37                0
## 6      -70.81759    -84.46500                   37                0
##   gyros_dumbbell_y gyros_dumbbell_z accel_dumbbell_x accel_dumbbell_y
## 1            -0.02             0.00             -234               47
## 2            -0.02             0.00             -233               47
## 3            -0.02             0.00             -232               46
## 4            -0.02            -0.02             -232               48
## 5            -0.02             0.00             -233               48
## 6            -0.02             0.00             -234               48
##   accel_dumbbell_z magnet_dumbbell_x magnet_dumbbell_y magnet_dumbbell_z
## 1             -271              -559               293               -65
## 2             -269              -555               296               -64
## 3             -270              -561               298               -63
```

```
## 4             -269              -552               303               -60
## 5             -270              -554               292               -68
## 6             -269              -558               294               -66
##   roll_forearm pitch_forearm yaw_forearm total_accel_forearm gyros_forearm_x
## 1         28.4         -63.9        -153                 36            0.03
## 2         28.3         -63.9        -153                 36            0.02
## 3         28.3         -63.9        -152                 36            0.03
## 4         28.1         -63.9        -152                 36            0.02
## 5         28.0         -63.9        -152                 36            0.02
## 6         27.9         -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 classe
## 1            -215              -17              654              476      A
## 2            -216              -18              661              473      A
## 3            -213              -18              658              469      A
## 4            -214              -16              658              469      A
## 5            -214              -17              655              473      A
## 6            -215               -9              660              478      A
```

We'll use K-fold validation with K = 3:

```
train.control <- trainControl(method="cv", number=1, verboseIter=TRUE)
```

We train a model using random forests:

```
fit <- train(classe ~ ., data=training, method="rf", trControl=train.control)
summary(fit)
```

Now we run prediction on the test set based on our fitted model:

```
testing <- testing[, colSums(is.na(testing)) < 1][-c(1:6,60)]
predict(fit, testing)
```