**Study design**

*Summary of raw data*

The raw data were collected by Anguita et al. (2012) [[1]](#footnote-1) and are freely available at:

<http://archive.ics.uci.edu/ml/datasets/Human+Activity+Recognition+Using+Smartphones>

As explained by Anguita et al. (2012), their data have been collected in experiments with a group of 30 volunteers within an age bracket of 19-48 years. Each person performed six activities (WALKING, WALKING\_UPSTAIRS, WALKING\_DOWNSTAIRS, SITTING, STANDING, LAYING) wearing a smartphone (Samsung Galaxy S II) on the waist. Using its embedded accelerometer and gyroscope, Anguita et al. captured 3-axial linear acceleration and 3-axial angular velocity at a constant rate of 50Hz. The experiments have been video-recorded to label the data manually. The obtained dataset has been randomly partitioned into two sets, where 70% of the volunteers was selected for generating the training data and 30% the test data.

The features selected for this database come from the accelerometer and gyroscope 3-axial raw signals tAcc-XYZ and tGyro-XYZ. These time domain signals (prefix 't' to denote time) were captured at a constant rate of 50 Hz. Then they were filtered using a median filter and a 3rd order low pass Butterworth filter with a corner frequency of 20 Hz to remove noise. Similarly, the acceleration signal was then separated into body and gravity acceleration signals (tBodyAcc-XYZ and tGravityAcc-XYZ) using another low pass Butterworth filter with a corner frequency of 0.3 Hz.

Subsequently, the body linear acceleration and angular velocity were derived in time to obtain Jerk signals (tBodyAccJerk-XYZ and tBodyGyroJerk-XYZ). Also the magnitude of these three-dimensional signals were calculated using the Euclidean norm (tBodyAccMag, tGravityAccMag, tBodyAccJerkMag, tBodyGyroMag, tBodyGyroJerkMag).

Finally a Fast Fourier Transform (FFT) was applied to some of these signals producing fBodyAcc-XYZ, fBodyAccJerk-XYZ, fBodyGyro-XYZ, fBodyAccJerkMag, fBodyGyroMag, fBodyGyroJerkMag. (Note the 'f' to indicate frequency domain signals).

These signals were used to estimate variables of the feature vector for each pattern:

'-XYZ' is used to denote 3-axial signals in the X, Y and Z directions.

tBodyAcc-XYZ

tGravityAcc-XYZ

tBodyAccJerk-XYZ

tBodyGyro-XYZ

tBodyGyroJerk-XYZ

tBodyAccMag

tGravityAccMag

tBodyAccJerkMag

tBodyGyroMag

tBodyGyroJerkMag

fBodyAcc-XYZ

fBodyAccJerk-XYZ

fBodyGyro-XYZ

fBodyAccMag

fBodyAccJerkMag

fBodyGyroMag

fBodyGyroJerkMag

The set of variables that were estimated from these signals are:

|  |  |
| --- | --- |
| mean() | Mean value |
| std() | Standard deviation |
| mad() | Median absolute deviation |
| max() | Largest value in array |
| min() | Smallest value in array |
| sma() | Signal magnitude area |
| energy() | Energy measure. Sum of the squares divided by the number of values. |
| iqr() | Interquartile range |
| entropy() | Signal entropy |
| arCoeff() | Autorregresion coefficients with Burg order equal to 4 |
| correlation() | correlation coefficient between two signals |
| maxInds() | index of the frequency component with largest magnitude |
| meanFreq() | Weighted average of the frequency components to obtain a mean frequency |
| skewness() | skewness of the frequency domain signal |
| kurtosis() | kurtosis of the frequency domain signal |
| bandsEnergy() | Energy of a frequency interval within the 64 bins of the FFT of each window. |
| angle() | Angle between to vectors |

Additional vectors obtained by averaging the signals in a signal window sample. These were used on the angle() variable:

gravityMean

tBodyAccMean

tBodyAccJerkMean

tBodyGyroMean

tBodyGyroJerkMean

*Performed manipulations*

From these raw data, we have selected all the variables expressing the means (mean()) and the standard deviations (std()) of each feature. For each subject-activity pair, we have then calculated the average value of these means and standard deviations for each feature.

**Codebook**

In the table below, “average value” is short-hand for “average value for each subject-activity” pair.

There are 6 activity labels and corresponding activity names (WALKING, WALKING\_UPSTAIRS, WALKING\_DOWNSTAIRS, SITTING, STANDING, LAYING). There are 30 subjects, identified by numbers ranging from 1 to 30.

Moreover:

* “gravity acceleration signal” refers to the acceleration signal from the smartphone accelerometer in standard gravity units 'g' (m/s2).
* “body acceleration signal” refers to the signal obtained by subtracting the gravity from the total acceleration(m/s2).
* “ angular velocity” is measured by the gyroscope for each window sample and is expressed in radians/second.

|  |  |
| --- | --- |
| Variable name | Description |
| "label" | The original label of each activity |
| "activityname" | The name of each activity |
| "subject" | The code corresponding to each subject |
| "TimeSignBodyAccStanDevX" "TimeSignBodyAccStanDevY" "TimeSignBodyAccStanDevZ" | The average value of the standard deviation of the time domain body acceleration signal (X, Y and Z coordinates, respectively) |
| "TimeSignGravityAccStanDevX" "TimeSignGravityAccStanDevY"  "TimeSignGravityAccStanDevZ" | The average value of the standard deviation of the time domain gravity acceleration signal (X, Y and Z coordinates, respectively) |
| "TimeSignBodyAccJerkStanDevX"  "TimeSignBodyAccJerkStanDevY" "TimeSignBodyAccJerkStanDevZ" | The average value of the standard deviation of the time domain body linear acceleration jerk signal (X, Y and Z coordinates, respectively) |
| "TimeSignBodyGyroStanDevX" "TimeSignBodyGyroStanDevY"  "TimeSignBodyGyroStanDevZ" | The average value of the standard deviation of the time domain body angular velocity signal (X, Y and Z coordinates, respectively) |
| "TimeSignBodyGyroJerkStanDevX"  "TimeSignBodyGyroJerkStanDevY" "TimeSignBodyGyroJerkStanDevZ" | The average value of the standard deviation of the time domain body angular velocity jerk signal (X, Y and Z coordinates, respectively) |
| "TimeSignBodyAccMagStanDev" | The average value of the standard deviation of the magnitude of the time domain body acceleration signal |
| "TimeSignGravityAccMagStanDev" | The average value of the standard deviation of the magnitude of the time domain gravity acceleration signal |
| "TimeSignBodyAccJerkMagStanDev" | The average value of the standard deviation of the magnitude of the time domain body linear acceleration jerk signal |
| "TimeSignBodyGyroMagStanDev" | The average value of the standard deviation of the magnitude of the time domain body angular velocity signal |
| "TimeSignBodyGyroJerkMagStanDev" | The average value of the standard deviation of the magnitude of the time domain body angular velocity jerk signal |
| "FreqDomBodyAccStanDevX"  "FreqDomBodyAccStanDevY" "FreqDomBodyAccStanDevZ" | The average value of the standard deviation of the frequency domain body acceleration signal (X, Y and Z coordinates, respectively) |
| "FreqDomBodyAccJerkStanDevX" "FreqDomBodyAccJerkStanDevY"  "FreqDomBodyAccJerkStanDevZ" | The average value of the standard deviation of the frequency domain body linear acceleration jerk signal (X, Y and Z coordinates, respectively) |
| "FreqDomBodyGyroStanDevX"  "FreqDomBodyGyroStanDevY" "FreqDomBodyGyroStanDevZ | The average value of the standard deviation of the frequency domain body angular velocity signal (X, Y and Z coordinates, respectively) |
| "FreqDomBodyAccMagStanDev" | The average value of the standard deviation of magnitude of the frequency domain body acceleration signal |
| "FreqDomBodyBodyAccJerkMagStanDev" | The average value of the standard deviation of the magnitude of the frequency domain body linear acceleration jerk signal |
| "FreqDomBodyBodyGyroMagStanDev" | The average value of the standard deviation of the magnitude of the frequency domain body angular velocity signal |
| "FreqDomBodyBodyGyroJerkMagStanDev" | The average value of the standard deviation of the magnitude of the frequency domain body angular velocity jerk signal |
| "TimeSignBodyAccMeanX" "TimeSignBodyAccMeanY"  "TimeSignBodyAccMeanZ" | The average value of the mean of the time domain body acceleration signal (X, Y and Z coordinates, respectively) |
| "TimeSignGravityAccMeanX"  “TimeSignGravityAccMeanY" "TimeSignGravityAccMeanZ" | The average value of the mean of the time domain gravity acceleration signal (X, Y and Z coordinates, respectively) |
| "TimeSignBodyAccJerkMeanX" "TimeSignBodyAccJerkMeanY"  "TimeSignBodyAccJerkMeanZ" | The average value of the mean of the time domain body linear acceleration jerk signal (X, Y and Z coordinates, respectively) |
| "TimeSignBodyGyroMeanX"  "TimeSignBodyGyroMeanY" "TimeSignBodyGyroMeanZ" | The average value of the mean of the time domain body angular velocity signal (X, Y and Z coordinates, respectively) |
| "TimeSignBodyGyroJerkMeanX" "TimeSignBodyGyroJerkMeanY"  "TimeSignBodyGyroJerkMeanZ" | The average value of the mean of the time domain body angular velocity jerk signal (X, Y and Z coordinates, respectively) |
| "TimeSignBodyAccMagMean" | The average value of the mean of the magnitude of the time domain body acceleration signal |
| "TimeSignGravityAccMagMean" | The average value of the mean of the magnitude of the time domain gravity acceleration signal |
| "TimeSignBodyAccJerkMagMean" | The average value of the mean of the magnitude of the time domain body linear acceleration jerk signal |
| "TimeSignBodyGyroMagMean" | The average value of the magnitude of the mean of the time domain body angular velocity signal |
| "TimeSignBodyGyroJerkMagMean" | The average value of the mean of the magnitude of the time domain body angular velocity jerk signal |
| "FreqDomBodyAccMeanX" "FreqDomBodyAccMeanY"  "FreqDomBodyAccMeanZ" | The average value of the mean of the frequency domain body acceleration signal (X, Y and Z coordinates, respectively) |
| "FreqDomBodyAccJerkMeanX"  "FreqDomBodyAccJerkMeanY" "FreqDomBodyAccJerkMeanZ" | The average value of the mean of the frequency domain body linear acceleration jerk signal (X, Y and Z coordinates, respectively) |
| "FreqDomBodyGyroMeanX" "FreqDomBodyGyroMeanY"  "FreqDomBodyGyroMeanZ" | The average value of the mean of the frequency domain body angular velocity signal (X, Y and Z coordinates, respectively) |
| "FreqDomBodyAccMagMean" | The average value of the mean of the magnitude of the frequency domain body acceleration signal |
| "FreqDomBodyBodyAccJerkMagMean" | The average value of the mean of the magnitude of the frequency domain body linear acceleration jerk signal |
| "FreqDomBodyBodyGyroMagMean " | The average value of the mean of the magnitude of the frequency domain body angular velocity signal |
| "FreqDomBodyBodyGyroJerkMagMean" | The average value of the mean of the magnitude of the frequency domain body angular velocity jerk signal |

1. Davide Anguita, Alessandro Ghio, Luca Oneto, Xavier Parra and Jorge L. Reyes-Ortiz. Human Activity Recognition on Smartphones using a Multiclass Hardware-Friendly Support Vector Machine. International Workshop of Ambient Assisted Living (IWAAL 2012). Vitoria-Gasteiz, Spain. Dec 2012. [↑](#footnote-ref-1)