Human Activity Recognition Using Smartphones' Data Code Book

The experiments have been carried out 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, we 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 sensor signals (accelerometer and gyroscope) were pre-processed by applying noise filters and then sampled in fixed-width sliding windows of 2.56 sec and 50% overlap (128 readings/window). The sensor acceleration signal, which has gravitational and body motion components, was separated using a Butterworth low-pass filter into body acceleration and gravity. The gravitational force is assumed to have only low frequency components, therefore a filter with 0.3 Hz cutoff frequency was used. From each window, a vector of features was obtained by calculating variables from the time and frequency domain.

Feature Selection
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The features selected for this database come from the accelerometer and gyroscope 3-axial raw signals timeAccelerometer-XYZ and timeGyroscop-XYZ. These time domain signals 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 (timeBodyAccelerometer-XYZ and timeGravityAccelerometer-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 (timeB

odyAccelerometerJerk-XYZ and timeBodyGyroscopJerk-XYZ). Also the magnitude of these three-dimensional signals were calculated using the Euclidean norm (timeBodyAccAccelerometerMagnitude, timeGravityAccelerometerMagnitude, timeBodyAccelerometerJerkMagnitude, timeBodyGGyroscopMagnitude, timeBodyGyroscopJerkMagnitude).

Finally a Fast Fourier Transform (FFT) was applied to some of these signals producing frequencyBodyAccelerometer-XYZ, frequencyBodyAccelerometerJerk-XYZ, frequencyBodyGyroscop-XYZ, frequencyBodyAccelerometerJerkMagnitude, frequencyBodyGyroscopMagnitude, frequencyBodyGyroscopJerkMagnitude.

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.

timeBodyAccelerometer-XYZ
timeGravityAccelerometer-XYZ
timeBodyAccelerometerJerk-XYZ
timeBodyGyroscop-XYZ
timeBodyGyroscopJerk-XYZ
timeBodyAccelerometerMagnitude
timeGravityAccelerometerMagnitude
timeBodyAccelerometerJerkMagnitude
timeBodyGyroscopMagnitude
timeBodyGyroscopJerkMagnitude
frequencyBodyAccelerometer-XYZ
frequencyBodyAccelerometerJerk-XYZ
frequencyBodyGyroscop-XYZ
frequencyBodyAccelerometerMagnitude
frequencyBodyAccelerometerJerkMagnitude
frequencyBodyGyroscopMagnitude
frequencyBodyGyroscopJerkMagnitude

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 are used on the angle() variable:

gravityMean
timeBodyAcceleratorMean
timeBodyAcceleratorJerkMean
timeBodyGyroscopMean
timeBodyGyroscopJerkMean

The complete list of variables of each feature vector is as following:
[1] "participants"
The name of participants.
[2] "activities"
The name of activities (WALKING, WALKING_UPSTAIRS, WALKING_DOWNSTAIRS, SITTING, STANDING, LAYING)

[3] "timeBodyAccelerator-mean()-X"
[4] "timeBodyAccelerator-mean()-Y"
[5] "timeBodyAccelerator-mean()-Z"
[6] "timeBodyAccelerator-std()-X"
[7] "timeBodyAccelerator-std()-Y"
[8] "timeBodyAccelerator-std()-Z"

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 [9] "timeBodyAccelerator-mad()-X"
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[230] "timeBodyAcceleratorJerkMagnitude-std()"

[231] "timeBodyAcceleratorJerkMagnitude-mad()"

[232] "timeBodyAcceleratorJerkMagnitude-max()"

[233] "timeBodyAcceleratorJerkMagnitude-min()"

[234] "timeBodyAcceleratorJerkMagnitude-sma()"

[235] "timeBodyAcceleratorJerkMagnitude-energy()"

[236] "timeBodyAcceleratorJerkMagnitude-iqr()"

[237] "timeBodyAcceleratorJerkMagnitude-entropy()"

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[361] "frequencyBodyAcceleratorJerk-bandsEnergy()-41,48"
[362] "frequencyBodyAcceleratorJerk-bandsEnergy()-49,56"
[363] "frequencyBodyAcceleratorJerk-bandsEnergy()-57,64"
[364] "frequencyBodyAcceleratorJerk-bandsEnergy()-1,16"
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[366] "frequencyBodyAcceleratorJerk-bandsEnergy()-33,48"
[367] "frequencyBodyAcceleratorJerk-bandsEnergy()-49,64"
[368] "frequencyBodyAcceleratorJerk-bandsEnergy()-1,24"
[369] "frequencyBodyAcceleratorJerk-bandsEnergy()-25,48"
[370] "frequencyBodyGyroscope-mean()-X"
[371] "frequencyBodyGyroscope-mean()-Y"
[372] "frequencyBodyGyroscope-mean()-Z"
[373] "frequencyBodyGyroscope-std()-X"
[374] "frequencyBodyGyroscope-std()-Y"
[375] "frequencyBodyGyroscope-std()-Z"
[376] "frequencyBodyGyroscope-mad()-X"
[377] "frequencyBodyGyroscope-mad()-Y"
[378] "frequencyBodyGyroscope-mad()-Z"
[379] "frequencyBodyGyroscope-max()-X"
[380] "frequencyBodyGyroscope-max()-Y"
[381] "frequencyBodyGyroscope-max()-Z"
[382] "frequencyBodyGyroscope-min()-X"
[383] "frequencyBodyGyroscope-min()-Y"
[384] "frequencyBodyGyroscope-min()-Z"
[385] "frequencyBodyGyroscope-sma()"
[386] "frequencyBodyGyroscope-energy()-X"
[387] "frequencyBodyGyroscope-energy()-Y"
[388] "frequencyBodyGyroscope-energy()-Z"
[389] "frequencyBodyGyroscope-iqr()-X"
[390] "frequencyBodyGyroscope-iqr()-Y"
[391] "frequencyBodyGyroscope-iqr()-Z"
[392] "frequencyBodyGyroscope-entropy()-X"
[393] "frequencyBodyGyroscope-entropy()-Y"
[394] "frequencyBodyGyroscope-entropy()-Z"
[395] "frequencyBodyGyroscope-maxInds-X"
[396] "frequencyBodyGyroscope-maxInds-Y"
[397] "frequencyBodyGyroscope-maxInds-Z"
[398] "frequencyBodyGyroscope-meanFreq()-X"
[399] "frequencyBodyGyroscope-meanFreq()-Y"
[400] "frequencyBodyGyroscope-meanFreq()-Z"
[401] "frequencyBodyGyroscope-skewness()-X"
[402] "frequencyBodyGyroscope-kurtosis()-X"
[403] "frequencyBodyGyroscope-skewness()-Y"
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[404] "frequencyBodyGyroscope-kurtosis()-Y"
[405] "frequencyBodyGyroscope-skewness()-Z"
[406] "frequencyBodyGyroscope-kurtosis()-Z"
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[408] "frequencyBodyGyroscope-bandsEnergy()-9,16"
[409] "frequencyBodyGyroscope-bandsEnergy()-17,24"
[410] "frequencyBodyGyroscope-bandsEnergy()-25,32"
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[413] "frequencyBodyGyroscope-bandsEnergy()-49,56"
[414] "frequencyBodyGyroscope-bandsEnergy()-57,64"
[415] "frequencyBodyGyroscope-bandsEnergy()-1,16"
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[418] "frequencyBodyGyroscope-bandsEnergy()-49,64"
[419] "frequencyBodyGyroscope-bandsEnergy()-1,24"
[420] "frequencyBodyGyroscope-bandsEnergy()-25,48"
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[422] "frequencyBodyAcceleratorMagnitude-std()"
[423] "frequencyBodyAcceleratorMagnitude-mad()"
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[425] "frequencyBodyAcceleratorMagnitude-min()"
[426] "frequencyBodyAcceleratorMagnitude-sma()"
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[427] "frequencyBodyAcceleratorMagnitude-energy()"
[428] "frequencyBodyAcceleratorMagnitude-iqr()"
[429] "frequencyBodyAcceleratorMagnitude-entropy()"
[430] "frequencyBodyAcceleratorMagnitude-maxInds"
[431] "frequencyBodyAcceleratorMagnitude-meanFreq()"
[432] "frequencyBodyAcceleratorMagnitude-skewness()"
[433] "frequencyBodyAcceleratorMagnitude-kurtosis()"
[434] "frequencyBodyBodyAcceleratorJerkMagnitude-mean()"
[435] "frequencyBodyBodyAcceleratorJerkMagnitude-std()"
[436] "frequencyBodyBodyAcceleratorJerkMagnitude-mad()"
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[438] "frequencyBodyBodyAcceleratorJerkMagnitude-min()"
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[442] "frequencyBodyBodyAcceleratorJerkMagnitude-entropy
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[443] "frequencyBodyBodyAcceleratorJerkMagnitude-maxInds"
[444] "frequencyBodyBodyAcceleratorJerkMagnitude-meanFreq
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[445] "frequencyBodyBodyAcceleratorJerkMagnitude-skewness
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[446] "frequencyBodyBodyAcceleratorJerkMagnitude-kurtosis
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[447] "frequencyBodyBodyGyroscopeMagnitude-mean()"
[448] "frequencyBodyBodyGyroscopeMagnitude-std()"
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[449] "frequencyBodyBodyGyroscopeMagnitude-mad()"

[450] "frequencyBodyBodyGyroscopeMagnitude-max()"

[451] "frequencyBodyBodyGyroscopeMagnitude-min()"

[452] "frequencyBodyBodyGyroscopeMagnitude-sma()"

[453] "frequencyBodyBodyGyroscopeMagnitude-energy()"

[454] "frequencyBodyBodyGyroscopeMagnitude-iqr()"

[455] "frequencyBodyBodyGyroscopeMagnitude-entropy()"

[456] "frequencyBodyBodyGyroscopeMagnitude-maxInds"

[457] "frequencyBodyBodyGyroscopeMagnitude-meanFreq()"

[458] "frequencyBodyBodyGyroscopeMagnitude-skewness()"

[459] "frequencyBodyBodyGyroscopeMagnitude-kurtosis()"

[460] "frequencyBodyBodyGyroscopeJerkMagnitude-mean()"

[461] "frequencyBodyBodyGyroscopeJerkMagnitude-std()"

[462] "frequencyBodyBodyGyroscopeJerkMagnitude-mad()"

[463] "frequencyBodyBodyGyroscopeJerkMagnitude-max()"

[464] "frequencyBodyBodyGyroscopeJerkMagnitude-min()"

[465] "frequencyBodyBodyGyroscopeJerkMagnitude-sma()"

[466] "frequencyBodyBodyGyroscopeJerkMagnitude-energy()"

[467] "frequencyBodyBodyGyroscopeJerkMagnitude-iqr()"

[468] "frequencyBodyBodyGyroscopeJerkMagnitude-entropy()"

[469] "frequencyBodyBodyGyroscopeJerkMagnitude-maxInds"

[470] "frequencyBodyBodyGyroscopeJerkMagnitude-meanFreq()
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[471] "frequencyBodyBodyGyroscopeJerkMagnitude-skewness()
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[472] "frequencyBodyBodyGyroscopeJerkMagnitude-kurtosis()
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[474] "angle(tBodyAcceleratorJerkMean),gravityMean)"

[475] "angle(tBodyGyroscopeMean,gravityMean)"
[476] "angle(tBodyGyroscopeJerkMean,gravityMean)"

[477] "angle(X,gravityMean)"
[478] "angle(Y,gravityMean)"
[479] "angle(Z,gravityMean)"
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