Title: Predicting mobile phone user's activity based on data collected by the phone's accelerometer and gyroscope

Introduction:

Modern mobile phones have many useful features, among which are motion-detecting sensors like accelerometer and gyroscope. Data recorded by these sensors may be analyzed and applied for useful purposes like fitness and health tracking applications [1].

Different patterns of movements are attributed to different activities performed by an individual mobile phone's user. We performed an analysis based on the data collected by Samsung Galaxy S II smartphones [2]. The purpose of this analysis is to build a predictive model that will detect by the measured motion characteristics, which activity a subject is performing at the time of measurement: laying, sitting, standing, walking, walking down the stairs or walking up the stairs.

An accelerometer measures movement along a particular axis (up and down, left and right, forward and backward). Samsung Galaxy S II used to gather this data can measure movement along all three of the X, Y and Z axes. The data that we used for modeling contained various measurements in X, Y and Z axis.

A gyroscope measures the orientation of the phone and how quickly it is changing orientation. The gyroscope axes are the same as the accelerometer axes. Positive values indicate counter-clockwise rotation around the axis and negative values indicate clockwise rotation around the axis. Acceleration measures the change in velocity of the phone; jerk measures the change in acceleration. Both could be useful for analyzing subject's activity. [1][3]

We analyzed the degree of importance of different motion parameters stored in data variables for detecting the activity that a subject is performing. We paid special attention to building a stable prediction model that will not be excessively tuned to the data set that we used to train the model.

Methods and Steps:

Data Collection

For our modeling we downloaded the data consisting of a sample of 7,352 observations [2]. The data was downloaded from Coursera web site, Data

Assignments page of Data Analysis course using R Studio programming and analysis software on Monday, March 04, 2013.

Exploratory Analysis

Exploratory analysis was performed by examining plots of the observed data. We identified transformations to perform on the data based on plots and our knowledge of the applicable functions. Exploratory analysis was used to (a) identify missing values, (b) verify the quality of the data, and (c) determine the variables that may be used to build the predictive model.

Prediction Functions

To perform robust classification prediction on the given multiple variables we applied decision trees and random forests techniques [4][5]. Model selection was performed on the basis of our exploratory analysis and prior knowledge of predictive classification models. Random forest function was executed with parameters prox=TRUE and importance=TRUE, all other parameters had default values.

Error Rates

We used misclassification error rate as the main error measure to determine final model precision as well as stability during cross-validation tests calculated by formula *er=count misclassified/count total* [6]. We also used confusion matrix as additional means of determining the precision of the models [7].

Training, Validation and Test Sets

The data used for modeling contained observations for 21 different individuals (represented by variable "*subject*" having values from 1 to 30). There were 281-408 records for every subject. We selected observations for individuals 1, 3, 5, 6, 16, 19, 23, 21 as our *training data set* (2821 rows). We used data for individuals 7, 8, 11, 14, 15, 17, 25, 26 as *validation/tuning data set* (2725 rows). The *final test data set* contained observations for subjects 22, 27, 28, 29 and 30 (1806 rows).

Features/Variables Selection

Our data set contained 563 variables, 561 of which represented numeric measures by accelerometer and gyroscope. Considering the limited scope of our modeling project, we did not perform a comprehensive analysis to find individual associations between variables and to eliminate closely correlated couples of variables that follow similar patterns. Instead we applied random forest algorithm to determine and select the most important variables. As a result having analyzed the tables and the plot (Figure 1) that depicts variable importance using Gini coefficient [8] we selected 111 most important variables. Then we built and compared trees and random forests based on all the 561 variables with trees and random forests based on the 111 most important variables to decide if the subset of variables was a better choice.

Validation, Cross-Validation and Testing

We applied a two-step validation strategy to ensure that the best approach was chosen. First we performed k-fold cross-validation with 5-fold and 10-fold validation [9]. In particular we divided the Training set into 5 (and then 10) segments, every time we used 4/5 (9/10) of the training set rows as training set and the remaining 1/5 (1/10) rows as test set. This was repeated 5 and then 10 times to cover all the records in the training set and to assess model stability and mean error rates. Then we trained the models on the entire training set and we validated them on the bigger validation set to check how the prediction would work on a completely new data set. Based on the outcome of these steps the model was adjusted and retrained on the entire training set. Finally, the test set was used to calculate the final error rates.

Reproducibility

All analyses performed can be reproduced in the R file samsungPredictFinal.R. Due to security concerns the source code of the analysis was not published, it can be requested separately.

Results:

Every column in our data set, except for the last two columns, represents one measurement from the Samsung phone. The variable *subject* indicates who was performing the action when the measurements were taken. The variable *activity* indicates what action they were engaged in. Most of the variables have three instances – each for one of the axes X, Y and Z. The full list of variables (with selected 111 variables) can be found in Appendix A. Also the description of variables can be found in the codebook [10].

We identified no missing values or abnormal outliers in the data. We converted the activity column to a factor to work with classification models. We used *subject* column to divide the data into training, validation and test data sets as described above.

Due to the fact that the variable names contained illegal characters (like brackets) that prevented the dataset from being used in the models, we applied a transformation to the names that replaced such characters in variable names with periods. Also there were duplicate column names. The analysis of the data in those columns indicates that they are different columns with different values. We fixed the names and left all the columns in place for analysis. So these fixes did not change the underlying data.

Considering complex nature of the data and the high number of variables we did not consider using logistic models. The most appropriate types of models for this data set are classification trees. Our initial modeling showed that the trees were very specific and they needed pruning that in turn increased classification error rate. So we decided to build a random forest model to utilize its robust automatic boot strapping algorithms. Our initial forest allowed assessing the influence (importance) of variables (see Figure 1). The plot demonstrates that most of the variables have little influence and only top 100 variables or so have important influence on the outcome. Due to the fact that the random forest that was built on all the columns has two major disadvantages (performance and potential over fitting) we decided to perform cross-validation using k-fold approach described above. We compared forests built on all variables with forests built on the top 111 most important variables. Also we included single tree model into cross-validation to compare random forest performance to trees. There was considerable difference in execution time between training the random forest model for all the variables and the limited top 111 variables. Limiting the number of variables gave us serious time improvement.

Table below summarizes cross-validation results that suggest that random forest with top 111 variables is the best variant considering precision, stability and response time.

Cross validation, 5-fold	Random Forest	Random Forest	Random Forest	Tree
Mean Correct classification %	98.05%	95.92%	98.21%	89.29%
Scope	All vars	51 top vars	111 top vars	tree 111 vars
Classification Error, Iteration 1	2.68%	2.61%	0.89%	5%
Classification Error, Iteration 2	1.79%	9.82%	3.57%	20%
Classification Error, Iteration 3	0.89%	2.68%	0.89%	4%
Classification Error, Iteration 4	1.79%	3.57%	1.79%	13%
Classification Error, Iteration 5	2.61%	1.74%	1.79%	12%
Mean classification error:	1.95%	4.08%	1.79%	11%
Classification Error Standard Deviation	0.73%	3.27%	1.09%	6%

We chose two models Random Forest (all variables) and Random Forest (111 top variables) to perform validation on the validation data set. This validation showed similar results and confirmed our choice of the model.

We performed final test of the models on the test data set and got the following results:

	Random forest (all variables)	Random forest (top 111 variables)
Actual Misclassification error rate:	**5.15%**	**6.53%**
OOB estimate of error rate	1.10%	1.45%

The final confusion matrix for the chosen model (random forest with top 111 variables) is shown below:

Confusion matrix:

	laying	sitting	standing	walk	walk down	walkup	class.error
laying	536	0	0	0	0	0	0.00000000
sitting	0	487	6	0	0	0	0.01217039
standing	0	14	521	0	0	0	0.02616822
walk	0	0	0	475	4	1	0.01041667
walk down	0	0	0	3	369	6	0.02380952
walkup	0	0	0	1	6	392	0.01754386

Conclusions:

We have built a model that predicts a person’s activity based on the metrics from their mobile phone’s motion sensors. The model is based on the robust random forest algorithm which is one of the most appropriate models in this case. We mitigated the risk of over fitting the model and making it too computationally intensive by limiting the number of variables to the top 111 variables that have the most influence on the model. This gave us the proper balance between model stability and precision. Our model can be used as a basic algorithm for predicting person’s activity for entertainment applications, however a more advanced study would be needed to build a more precise model that would better distinguish between the similar activities like walking, walking up and down as well as standing and sitting. Also a more comprehensive study of variables and their relationships is necessary to exclude potentially correlated confounders. A bigger training sample may be required to refine the model as well as a combination with other classification algorithms may improve the model’s accuracy.

References

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Rnk	Variable	Gini	Rnk	Variable	Gini	Rnk	Variable	Gini
1	angle.X.gravityMean.	71.85	57	tGravityAcc.sma..	11.65	113	tGravityAccMag.max..	4.98
2	tGravityAcc.min...X	68.97	58	fBodyAccJerk.entropy...X	11.48	114	tGravityAcc.arCoeff...Z.3	4.98
3	tGravityAcc.energy...X	66.16	59	tBodyAccMag.mad..	11.27	115	tBodyGyroJerk.correlation...X.Y	4.89
4	tGravityAcc.max...X	63.93	60	tBodyAcc.mad...X	11.06	116	fBodyAccJerk.bandsEnergy...1.8.1	4.83
5	tGravityAcc.mean...X	62.00	61	tGravityAcc.arCoeff...Y.3	10.84	117	tBodyAccMag.max..	4.78
6	tGravityAcc.min...Y	58.05	62	fBodyAccMag.mean..	10.62	118	tBodyGyro.max...X	4.76
7	angle.Y.gravityMean.	50.73	63	fBodyAccJerk.bandsEnergy...17.32	10.36	119	fBodyGyro.bandsEnergy...1.16	4.70
8	tGravityAcc.mean...Y	47.59	64	tBodyAccJerkMag.iqr..	9.95	120	tBodyGyroMag.arCoeff..1	4.60
9	tGravityAcc.max...Y	43.83	65	tGravityAcc.arCoeff...Z.2	9.79	121	tGravityAcc.arCoeff...Y.4	4.57
10	tGravityAcc.energy...Y	40.73	66	fBodyAccJerk.mean...X	9.72	122	tGravityAcc.entropy...X	4.50
11	tGravityAcc.min...Z	29.72	67	tBodyAccJerkMag.energy..	9.66	123	tBodyAccJerk.iqr...X	4.50
12	angle.Z.gravityMean.	29.65	68	fBodyAcc.std...X	9.53	124	fBodyGyro.maxInds.X	4.41
13	tGravityAcc.mean...Z	25.77	69	tBodyAccJerkMag.sma..	9.48	125	fBodyAccMag.entropy..	4.39
14	tGravityAcc.arCoeff...X.1	25.59	70	tBodyAccJerk.max...X	9.32	126	fBodyGyro.skewness...X	4.33
15	tGravityAcc.max...Z	25.58	71	tBodyGyroJerk.iqr...Z	8.99	127	fBodyAcc.entropy...X	4.26
16	tBodyAccJerk.std...X	24.07	72	tBodyAccJerkMag.std..	8.75	128	fBodyAcc.bandsEnergy...1.8.1	4.23
17	tGravityAcc.arCoeff...X.2	23.75	73	fBodyAcc.bandsEnergy...17.24	8.57	129	tBodyGyro.iqr...X	4.21
18	tBodyAcc.max...X	23.71	74	fBodyBodyAccJerkMag.std..	8.43	130	fBodyAccJerk.bandsEnergy...17.32.1	4.11
19	tGravityAcc.arCoeff...X.3	22.30	75	fBodyAccJerk.sma..	8.24	131	tBodyGyroJerk.arCoeff...X.2	3.99
20	fBodyAccMag.energy..	21.58	76	tBodyAcc.correlation...X.Y	7.82	132	fBodyBodyAccJerkMag.max..	3.99
21	tBodyAccMag.std..	20.15	77	fBodyAcc.skewness...X	7.82	133	fBodyGyro.bandsEnergy...1.24	3.92
22	fBodyAcc.energy...X	18.78	78	tBodyAccJerkMag.mad..	7.79	134	fBodyGyro.std...X	3.84
23	tGravityAccMag.std..	18.56	79	fBodyAccJerk.iqr...Y	7.69	135	fBodyAccJerk.bandsEnergy...33.48	3.80
24	fBodyAccJerk.max...X	18.40	80	tBodyAccMag.energy..	7.66	136	fBodyAccJerk.bandsEnergy...1.24.1	3.75
25	fBodyAccJerk.energy...X	18.13	81	fBodyBodyAccJerkMag.mad..	7.59	137	fBodyGyro.energy...X	3.74
26	fBodyAcc.bandsEnergy...1.16	17.89	82	tGravityAccMag.energy..	7.56	138	fBodyAccJerk.std...Y	3.74
27	tBodyAccJerk.energy...X	17.78	83	fBodyBodyGyroMag.meanFreq..	7.48	139	tBodyGyroJerk.mad...Z	3.68
28	fBodyAccMag.mad..	17.22	84	tGravityAcc.correlation...X.Y	7.41	140	tBodyGyroJerk.correlation...X.Z	3.63
29	fBodyAccJerk.bandsEnergy...1.8	17.20	85	tBodyAccJerk.min...X	7.40	141	tBodyAccJerkMag.max..	3.61
30	fBodyAcc.mean...X	16.02	86	tBodyAccJerk.iqr...Y	7.07	142	tBodyAccJerk.entropy...Z	3.55
31	fBodyAccMag.std..	16.00	87	fBodyBodyAccJerkMag.iqr..	7.04	143	tBodyAccJerk.energy...Y	3.49
32	fBodyAcc.mad...X	15.56	88	fBodyAccJerk.mad...Y	7.03	144	fBodyAccMag.iqr..	3.43
33	tBodyAccJerk.mad...X	15.35	89	fBodyBodyAccJerkMag.energy..	6.98	145	fBodyAcc.std...Y	3.40
34	tGravityAcc.arCoeff...X.4	15.24	90	fBodyAcc.max...X	6.92	146	tBodyGyro.arCoeff...X.1	3.40
35	tGravityAccMag.mad..	14.74	91	fBodyGyro.meanFreq...X	6.91	147	fBodyAcc.bandsEnergy...9.16	3.38
36	fBodyAccJerk.bandsEnergy...1.24	14.11	92	fBodyBodyAccJerkMag.mean..	6.75	148	tGravityAcc.correlation...Y.Z	3.37
37	tGravityAcc.arCoeff...Y.1	14.08	93	fBodyAccJerk.bandsEnergy...9.16	6.64	149	fBodyAcc.iqr...X	3.34
38	tBodyAccJerkMag.mean..	13.87	94	fBodyAccJerk.energy...Y	6.42	150	tBodyGyro.std...X	3.32
39	tBodyAcc.energy...X	13.62	95	tGravityAccMag.arCoeff..1	6.41	151	tBodyGyroJerk.arCoeff...X.1	3.27
40	fBodyAccJerk.bandsEnergy...17.24	13.38	96	tBodyAccJerk.entropy...X	6.16	152	tBodyGyroJerk.arCoeff...X.3	3.24
41	tBodyAcc.std...X	13.33	97	fBodyGyro.bandsEnergy...1.8	6.16	153	tBodyGyro.entropy...X	3.21
42	fBodyAcc.bandsEnergy...1.8	13.25	98	tBodyAccJerk.mad...Y	6.09	154	tBodyAcc.iqr...X	3.17
43	tBodyAccMag.arCoeff..1	13.21	99	fBodyAccMag.max..	6.01	155	tGravityAccMag.mean..	3.15
44	tGravityAcc.arCoeff...Y.2	13.13	100	tBodyAccJerkMag.entropy..	5.88	156	fBodyAcc.meanFreq...X	3.03
45	fBodyAccJerk.bandsEnergy...1.16	13.09	101	fBodyAccJerk.entropy...Y	5.79	157	tBodyGyro.min...X	2.95
46	fBodyBodyAccJerkMag.sma..	12.88	102	fBodyAccJerk.bandsEnergy...25.48	5.70	158	fBodyGyro.kurtosis...X	2.91
47	fBodyGyro.maxInds.Z	12.86	103	tBodyAcc.correlation...Y.Z	5.48	159	tGravityAccMag.iqr..	2.87
48	fBodyAccJerk.std...X	12.67	104	fBodyAccJerk.bandsEnergy...17.24.1	5.40	160	fBodyAccJerk.bandsEnergy...1.16.1	2.87
49	fBodyAcc.bandsEnergy...1.24	12.55	105	fBodyGyro.max...X	5.39	161	fBodyGyro.bandsEnergy...9.16	2.87
50	tGravityAcc.entropy...Y	12.51	106	fBodyAccJerk.max...Y	5.38	162	tBodyGyro.correlation...X.Y	2.80
51	tGravityAcc.energy...Z	12.49	107	fBodyAccJerk.bandsEnergy...41.48	5.37	163	tBodyGyroJerk.iqr...X	2.80
52	fBodyAccJerk.mad...X	12.32	108	fBodyAccMag.meanFreq..	5.24	164	tGravityAccMag.sma..	2.73
53	tBodyAccJerk.sma..	12.23	109	tBodyAccJerk.std...Y	5.13	165	fBodyGyro.mad...X	2.72
54	fBodyAccJerk.maxInds.X	12.03	110	tBodyGyro.mad...X	5.12	166	tBodyGyro.correlation...Y.Z	2.66
55	fBodyAccMag.sma..	11.68	111	fBodyAcc.bandsEnergy...17.32	5.09	167	tGravityAcc.mad...X	2.58
56	tGravityAcc.arCoeff...Z.1	11.67	112	fBodyAcc.kurtosis...X	5.00	168	tBodyAcc.energy...Y	2.58

Rnk	Variable	Gini	Rnk	Variable	Gini	Rnk	Variable	Gini
169	fBodyAcc.max...Y	2,57	225	fBodyGyro.bandsEnergy...1.24.2	1,57	281	fBodyGyro.skewness...Z	1,05
170	fBodyAcc.meanFreq...Z	2,48	226	fBodyAcc.bandsEnergy...17.24.1	1,55	282	fBodyBodyGyroMag.mad..	1,05
171	fBodyAccJerk.bandsEnergy...9.16.1	2,46	227	tBodyGyro.iqr...Y	1,55	283	fBodyAcc.max...Z	1,05
172	fBodyAcc.bandsEnergy...17.32.1	2,42	228	tBodyGyroJerk.correlation...Y.Z	1,52	284	fBodyGyro.std...Y	1,05
173	fBodyAcc.bandsEnergy...1.24.1	2,40	229	tBodyGyro.mean...Z	1,52	285	tBodyGyroJerk.entropy...X	1,03
174	fBodyAcc.bandsEnergy...9.16.1	2,40	230	fBodyAccJerk.mad...Z	1,50	286	fBodyAcc.bandsEnergy...1.16.2	1,03
175	tBodyAcc.entropy...X	2,38	231	fBodyAccJerk.bandsEnergy...49.56	1,48	287	tBodyAcc.arCoeff...X.4	1,02
176	tBodyGyroJerk.iqr...Y	2,36	232	fBodyGyro.bandsEnergy...25.48.1	1,48	288	tBodyGyroJerkMag.arCoeff..2	1,02
177	tGravityAcc.arCoeff...Z.4	2,35	233	tBodyGyro.sma..	1,48	289	tBodyAccMag.entropy..	1,01
178	tBodyAcc.mad...Y	2,32	234	fBodyAccJerk.mean...Z	1,45	290	tGravityAcc.correlation...X.Z	1,01
179	tGravityAcc.iqr...X	2,30	235	fBodyAcc.bandsEnergy...33.48	1,43	291	tBodyGyroMag.sma..	1,00
180	fBodyGyro.mean...X	2,29	236	tBodyAccJerk.entropy...Y	1,42	292	fBodyGyro.bandsEnergy...17.32.1	1,00
181	fBodyGyro.skewness...Y	2,29	237	fBodyAccJerk.bandsEnergy...25.48.1	1,41	293	tBodyAccJerk.arCoeff...Y.1	0,98
182	fBodyAccJerk.mean...Y	2,21	238	fBodyAcc.bandsEnergy...1.8.2	1,40	294	fBodyAcc.bandsEnergy...25.48	0,98
183	fBodyAcc.bandsEnergy...1.16.1	2,20	239	tBodyAccJerk.mad...Z	1,38	295	tBodyGyro.mean...X	0,97
184	fBodyGyro.kurtosis...Y	2,19	240	tBodyAcc.sma..	1,38	296	tBodyGyro.energy...Y	0,97
185	fBodyAcc.meanFreq...Y	2,19	241	tGravityAcc.iqr...Y	1,38	297	fBodyAccJerk.bandsEnergy...33.40	0,96
186	fBodyGyro.maxInds.Y	2,19	242	fBodyAcc.entropy...Y	1,38	298	tBodyAccJerk.correlation...Y.Z	0,96
187	tGravityAcc.std...Y	2,07	243	tBodyGyro.iqr...Z	1,36	299	fBodyGyro.bandsEnergy...17.24.1	0,96
188	tGravityAcc.std...X	2,07	244	tBodyGyro.min...Z	1,36	300	tBodyGyro.std...Y	0,96
189	tBodyAccMag.mean..	2,01	245	tGravityAcc.entropy...Z	1,34	301	fBodyBodyGyroMag.maxInds	0,96
190	tGravityAcc.mad...Y	1,98	246	angle.tBodyGyroMean.gravityMean.	1,34	302	tBodyGyroJerk.energy...Y	0,96
191	tBodyAccMag.sma..	1,95	247	tBodyGyroMag.mean..	1,34	303	tBodyGyroJerkMag.std..	0,96
192	tBodyGyro.entropy...Z	1,95	248	tBodyGyro.std...Z	1,32	304	tBodyAcc.mean...Y	0,95
193	tBodyGyroJerk.std...X	1,92	249	fBodyBodyGyroJerkMag.max..	1,31	305	fBodyAccJerk.iqr...X	0,94
194	tBodyAcc.correlation...X.Z	1,91	250	tBodyAccJerk.correlation...X.Z	1,29	306	fBodyAcc.kurtosis...Z	0,94
195	fBodyAcc.bandsEnergy...17.32.2	1,90	251	fBodyBodyAccJerkMag.entropy..	1,26	307	tBodyAccMag.iqr..	0,92
196	tBodyGyro.correlation...X.Z	1,88	252	fBodyAcc.skewness...Z	1,23	308	tBodyGyro.arCoeff...Y.4	0,92
197	fBodyGyro.entropy...X	1,86	253	fBodyBodyGyroJerkMag.skewness..	1,22	309	tBodyAccJerk.correlation...X.Y	0,91
198	tBodyGyroJerk.energy...X	1,85	254	tBodyGyroJerkMag.arCoeff..4	1,22	310	tBodyGyroJerkMag.entropy..	0,90
199	tBodyGyroMag.arCoeff..2	1,85	255	fBodyGyro.bandsEnergy...1.16.2	1,20	311	fBodyAcc.bandsEnergy...41.48	0,90
200	tBodyAcc.std...Y	1,84	256	fBodyGyro.bandsEnergy...17.32	1,20	312	tBodyGyroMag.arCoeff..3	0,89
201	tBodyGyro.energy...X	1,79	257	fBodyGyro.bandsEnergy...25.48.2	1,18	313	tBodyGyro.max...Y	0,89
202	fBodyGyro.bandsEnergy...17.24	1,78	258	fBodyGyro.energy...Z	1,18	314	angle.tBodyGyroJerkMean.gravityMean.	0,88
203	fBodyAcc.energy...Y	1,78	259	fBodyGyro.bandsEnergy...1.16.1	1,17	315	fBodyGyro.kurtosis...Z	0,88
204	tBodyGyroJerk.mad...X	1,77	260	tBodyAcc.iqr...Y	1,17	316	tBodyAcc.arCoeff...Y.2	0,88
205	fBodyGyro.std...Z	1,74	261	tGravityAcc.mad...Z	1,17	317	tGravityAccMag.entropy..	0,87
206	fBodyAccJerk.bandsEnergy...25.32.1	1,74	262	tBodyGyroJerkMag.mad..	1,13	318	fBodyGyro.bandsEnergy...25.48	0,87
207	fBodyAccJerk.bandsEnergy...17.24.2	1,73	263	tBodyGyroJerk.entropy...Z	1,13	319	fBodyAccJerk.kurtosis...Y	0,87
208	fBodyAccJerk.bandsEnergy...25.32	1,71	264	fBodyGyro.bandsEnergy...49.64.2	1,13	320	fBodyAcc.mad...Y	0,87
209	fBodyGyro.meanFreq...Z	1,70	265	fBodyGyro.bandsEnergy...25.32.2	1,12	321	tBodyAcc.energy...Z	0,86
210	fBodyBodyGyroJerkMag.std..	1,67	266	fBodyAccJerk.skewness...Y	1,12	322	fBodyGyro.iqr...Y	0,86
211	tGravityAccMag.arCoeff..2	1,66	267	fBodyGyro.bandsEnergy...17.32.2	1,12	323	fBodyAccJerk.bandsEnergy...17.32.2	0,86
212	fBodyAcc.skewness...Y	1,66	268	fBodyAcc.std...Z	1,11	324	tBodyGyro.mad...Y	0,86
213	tBodyGyro.energy...Z	1,66	269	tBodyGyroJerk.min...X	1,11	325	fBodyGyro.max...Y	0,86
214	fBodyAccJerk.bandsEnergy...33.48.1	1,65	270	fBodyGyro.max...Z	1,10	326	fBodyGyro.bandsEnergy...49.56.2	0,86
215	fBodyGyro.bandsEnergy...1.8.2	1,64	271	tBodyGyroMag.min..	1,10	327	tBodyGyroJerk.arCoeff...Y.1	0,86
216	tBodyAccJerk.min...Z	1,64	272	tBodyGyro.entropy...Y	1,10	328	fBodyAcc.bandsEnergy...17.24.2	0,85
217	tBodyAccJerk.iqr...Z	1,64	273	tBodyGyro.mad...Z	1,08	329	fBodyGyro.energy...Y	0,85
218	fBodyAcc.sma..	1,63	274	fBodyBodyGyroJerkMag.kurtosis..	1,08	330	fBodyAcc.energy...Z	0,85
219	tBodyAcc.min...Y	1,61	275	fBodyGyro.mad...Z	1,07	331	fBodyBodyGyroMag.std..	0,83
220	tBodyGyroJerk.max...X	1,61	276	tBodyGyro.arCoeff...Y.1	1,07	332	fBodyGyro.mean...Y	0,82
221	fBodyAccJerk.energy...Z	1,60	277	fBodyGyro.bandsEnergy...17.24.2	1,07	333	fBodyGyro.bandsEnergy...33.40.1	0,82
222	tBodyAccMag.arCoeff..2	1,60	278	fBodyGyro.bandsEnergy...57.64.2	1,06	334	fBodyAcc.mad...Z	0,82
223	fBodyGyro.bandsEnergy...25.32.1	1,59	279	fBodyAcc.kurtosis...Y	1,06	335	fBodyGyro.bandsEnergy...33.48	0,81
224	tBodyGyro.arCoeff...Z.4	1,58	280	tBodyGyroJerk.max...Y	1,06	336	tBodyGyro.max...Z	0,81

Rnk	Variable	Gini	Rnk	Variable	Gini	Rnk	Variable	Gini
337	tBodyAcc.max...Y	0,81	393	tBodyGyroJerk.arCoeff...Y.3	0,65	449	fBodyBodyGyroJerkMag.maxInds	0,54
338	tBodyAccJerkMag.arCoeff..2	0,81	394	tBodyGyroJerk.energy...Z	0,65	450	tBodyGyroJerk.arCoeff...Z.2	0,54
339	tBodyGyroJerk.arCoeff...Z.3	0,81	395	fBodyAcc.bandsEnergy...25.48.2	0,65	451	fBodyGyro.mad...Y	0,54
340	tBodyAcc.arCoeff...X.1	0,81	396	tBodyAccJerkMag.arCoeff..1	0,65	452	fBodyGyro.entropy...Z	0,54
341	tBodyGyro.arCoeff...X.4	0,81	397	fBodyBodyGyroMag.sma..	0,65	453	tBodyGyro.arCoeff...Y.3	0,54
342	tGravityAcc.std...Z	0,81	398	fBodyGyro.bandsEnergy...57.64	0,65	454	tBodyGyroJerkMag.iqr..	0,53
343	fBodyBodyGyroJerkMag.mad..	0,80	399	tBodyGyroMag.std..	0,65	455	tBodyAcc.min...Z	0,53
344	fBodyGyro.iqr...X	0,80	400	fBodyGyro.bandsEnergy...9.16.2	0,65	456	tBodyGyroJerkMag.energy..	0,53
345	fBodyAcc.bandsEnergy...25.32	0,80	401	fBodyBodyGyroMag.energy..	0,64	457	tBodyAcc.arCoeff...Z.1	0,53
346	fBodyAcc.bandsEnergy...33.40	0,79	402	tBodyAccJerk.energy...Z	0,64	458	fBodyGyro.bandsEnergy...49.56.1	0,52
347	fBodyGyro.min...Z	0,79	403	tBodyAccJerk.arCoeff...X.4	0,64	459	tBodyGyroJerk.arCoeff...Y.2	0,52
348	fBodyBodyAccJerkMag.skewness..	0,79	404	fBodyGyro.bandsEnergy...1.24.1	0,63	460	fBodyBodyGyroMag.mean..	0,52
349	tBodyAcc.max...Z	0,79	405	fBodyGyro.bandsEnergy...9.16.1	0,63	461	tBodyAccJerk.mean...X	0,52
350	fBodyGyro.meanFreq...Y	0,79	406	tBodyAccJerk.min...Y	0,63	462	tBodyAccJerk.arCoeff...Y.2	0,52
351	tBodyGyroJerk.std...Z	0,78	407	tBodyGyroMag.entropy..	0,62	463	tBodyAccJerkMag.min..	0,52
352	tBodyGyroJerk.std...Y	0,78	408	fBodyBodyGyroMag.max..	0,62	464	fBodyAccJerk.bandsEnergy...41.48.2	0,52
353	tBodyGyroJerk.mad...Y	0,78	409	fBodyGyro.bandsEnergy...41.48.2	0,62	465	fBodyGyro.bandsEnergy...57.64.1	0,51
354	fBodyGyro.bandsEnergy...33.40	0,78	410	fBodyBodyGyroMag.kurtosis..	0,62	466	fBodyBodyAccJerkMag.maxInds	0,51
355	fBodyBodyGyroJerkMag.meanFreq..	0,77	411	tBodyAccJerk.max...Z	0,62	467	tBodyGyroJerkMag.arCoeff..3	0,51
356	fBodyGyro.bandsEnergy...49.56	0,77	412	fBodyAccJerk.std...Z	0,61	468	tBodyAcc.iqr...Z	0,50
357	tBodyGyro.mean...Y	0,77	413	tBodyGyroJerk.mean...Z	0,61	469	fBodyAccJerk.maxInds.Y	0,50
358	fBodyBodyGyroJerkMag.energy..	0,76	414	fBodyGyro.bandsEnergy...49.64	0,61	470	fBodyBodyGyroMag.iqr..	0,50
359	tBodyGyroMag.arCoeff..4	0,76	415	fBodyAccJerk.meanFreq...Y	0,61	471	tBodyAccJerk.arCoeff...Z.2	0,50
360	tBodyGyroJerk.entropy...Y	0,76	416	fBodyAccMag.kurtosis..	0,61	472	fBodyBodyAccJerkMag.min..	0,50
361	fBodyAcc.maxInds.Y	0,75	417	tBodyAcc.entropy...Z	0,60	473	tBodyGyroJerk.sma..	0,50
362	fBodyAcc.bandsEnergy...25.32.2	0,75	418	fBodyAccJerk.kurtosis...X	0,60	474	fBodyAcc.bandsEnergy...33.40.2	0,50
363	fBodyAcc.mean...Y	0,75	419	fBodyAccJerk.bandsEnergy...1.16.2	0,60	475	tGravityAccMag.min..	0,49
364	tBodyAccJerk.arCoeff...X.1	0,75	420	tBodyAccJerk.arCoeff...Y.3	0,59	476	fBodyAccJerk.bandsEnergy...49.64.2	0,49
365	fBodyAccJerk.skewness...X	0,75	421	fBodyAccMag.skewness..	0,59	477	tBodyAccMag.min..	0,49
366	tBodyAcc.min...X	0,74	422	tBodyGyroMag.mad..	0,59	478	fBodyAccJerk.kurtosis...Z	0,48
367	tBodyGyroMag.energy..	0,73	423	tBodyAcc.arCoeff...Z.4	0,59	479	tBodyAcc.arCoeff...X.3	0,48
368	fBodyGyro.bandsEnergy...33.48.1	0,73	424	fBodyGyro.bandsEnergy...41.48	0,58	480	tBodyGyroMag.iqr..	0,48
369	tBodyAccJerkMag.arCoeff..3	0,73	425	fBodyGyro.bandsEnergy...33.40.2	0,58	481	tBodyAcc.entropy...Y	0,48
370	tBodyGyroJerk.min...Y	0,73	426	fBodyBodyGyroJerkMag.sma..	0,58	482	tBodyAcc.arCoeff...Y.4	0,48
371	fBodyGyro.bandsEnergy...33.48.2	0,73	427	tBodyAcc.arCoeff...Z.2	0,58	483	tBodyGyro.arCoeff...Z.1	0,47
372	fBodyAccJerk.bandsEnergy...25.32.2	0,73	428	fBodyAcc.bandsEnergy...1.24.2	0,58	484	tBodyGyroJerk.arCoeff...X.4	0,47
373	tBodyAccJerk.arCoeff...X.3	0,73	429	tBodyGyroJerk.mean...X	0,58	485	fBodyGyro.mean...Z	0,47
374	tBodyGyroJerk.arCoeff...Y.4	0,72	430	fBodyBodyGyroJerkMag.mean..	0,58	486	tBodyGyro.min...Y	0,47
375	tBodyGyroJerkMag.sma..	0,72	431	fBodyAcc.bandsEnergy...49.56.2	0,57	487	tBodyAcc.mean...X	0,46
376	fBodyAccJerk.bandsEnergy...1.8.2	0,71	432	tBodyGyro.arCoeff...X.2	0,57	488	angle.tBodyAccMean.gravity.	0,46
377	tBodyGyroJerkMag.arCoeff..1	0,71	433	fBodyAcc.maxInds.X	0,57	489	tBodyGyroJerkMag.min..	0,46
378	fBodyAccJerk.max...Z	0,71	434	tBodyAccJerkMag.arCoeff..4	0,57	490	tBodyAcc.arCoeff...Z.3	0,46
379	tBodyGyroJerkMag.mean..	0,70	435	fBodyGyro.entropy...Y	0,57	491	tBodyAccJerk.arCoeff...Z.1	0,46
380	tBodyAccJerk.arCoeff...Y.4	0,70	436	tBodyGyroJerk.arCoeff...Z.1	0,57	492	tBodyAcc.std...Z	0,46
381	fBodyAccJerk.bandsEnergy...25.48.2	0,70	437	fBodyAcc.bandsEnergy...9.16.2	0,57	493	fBodyAcc.bandsEnergy...41.48.2	0,46
382	fBodyBodyAccJerkMag.kurtosis..	0,70	438	fBodyAccJerk.meanFreq...X	0,56	494	fBodyBodyAccJerkMag.meanFreq..	0,45
383	fBodyAccJerk.meanFreq...Z	0,70	439	fBodyBodyGyroMag.skewness..	0,56	495	fBodyAccJerk.bandsEnergy...33.40.2	0,45
384	fBodyAccJerk.skewness...Z	0,69	440	fBodyAccJerk.maxInds.Z	0,56	496	fBodyAccJerk.bandsEnergy...1.24.2	0,45
385	tBodyAccJerk.std...Z	0,69	441	tBodyAccJerk.arCoeff...Z.4	0,56	497	fBodyAccMag.min..	0,44
386	fBodyAcc.entropy...Z	0,68	442	tBodyGyroJerkMag.max..	0,55	498	fBodyGyro.min...X	0,44
387	tBodyAcc.arCoeff...Y.1	0,68	443	tBodyAcc.mad...Z	0,55	499	tBodyGyro.arCoeff...Y.2	0,44
388	fBodyGyro.bandsEnergy...41.48.1	0,68	444	tBodyGyroJerk.max...Z	0,55	500	fBodyGyro.min...Y	0,44
389	fBodyGyro.bandsEnergy...1.8.1	0,67	445	tBodyAcc.mean...Z	0,55	501	fBodyAcc.bandsEnergy...33.48.2	0,44
390	tGravityAcc.iqr...Z	0,67	446	fBodyGyro.bandsEnergy...25.32	0,55	502	fBodyAccJerk.bandsEnergy...49.64.1	0,44
391	fBodyBodyGyroMag.min..	0,67	447	tBodyGyroJerk.arCoeff...Z.4	0,55	503	fBodyAcc.maxInds.Z	0,44
392	tBodyGyroJerk.min...Z	0,66	448	fBodyAcc.mean...Z	0,55	504	fBodyAccJerk.bandsEnergy...33.48.2	0,44

Rnk	Variable	Gini	Rnk	Variable	Gini	Rnk	Variable	Gini
505	tBodyAcc.arCoeff...X.2	0,43	559	fBodyAccJerk.min...X	0,27			
506	tBodyAccJerk.mean...Z	0,43	560	tBodyAccJerk.mean...Y	0,25			
507	tBodyAccMag.arCoeff..4	0,43	561	fBodyAcc.bandsEnergy...57.64	0,25			
508	fBodyAccJerk.bandsEnergy...41.48.1	0,43						
509	fBodyAccJerk.bandsEnergy...49.64	0,43						
510	tBodyGyro.arCoeff...Z.2	0,43						
511	tBodyGyro.arCoeff...Z.3	0,43						
512	fBodyGyro.iqr...Z	0,42						
513	tBodyAcc.arCoeff...Y.3	0,42						
514	fBodyGyro.sma..	0,42						
515	fBodyAccJerk.bandsEnergy...49.56.1	0,42						
516	fBodyAcc.bandsEnergy...49.56.1	0,42						
517	fBodyAcc.bandsEnergy...57.64.2	0,42						
518	fBodyAccJerk.bandsEnergy...57.64	0,41						
519	fBodyAccJerk.bandsEnergy...9.16.2	0,41						
520	fBodyGyro.bandsEnergy...49.64.1	0,41						
521	fBodyAcc.iqr...Z	0,41						
522	fBodyAccMag.maxInds	0,40						
523	tBodyGyro.arCoeff...X.3	0,40						
524	fBodyAccJerk.bandsEnergy...49.56.2	0,39						
525	tGravityAccMag.arCoeff..4	0,39						
526	tBodyAccJerk.max...Y	0,39						
527	fBodyAccJerk.min...Y	0,38						
528	fBodyAcc.bandsEnergy...49.64.2	0,38						
529	fBodyBodyGyroJerkMag.iqr..	0,37						
530	fBodyAccJerk.iqr...Z	0,37						
531	fBodyAcc.min...Z	0,37						
532	fBodyBodyGyroJerkMag.min..	0,37						
533	fBodyAcc.bandsEnergy...33.48.1	0,37						
534	fBodyAcc.min...X	0,36						
535	fBodyAcc.min...Y	0,36						
536	tBodyGyroJerk.mean...Y	0,36						
537	fBodyAccJerk.bandsEnergy...57.64.2	0,36						
538	fBodyAcc.bandsEnergy...25.48.1	0,35						
539	fBodyAccJerk.bandsEnergy...57.64.1	0,35						
540	fBodyAccJerk.bandsEnergy...33.40.1	0,35						
541	fBodyBodyGyroJerkMag.entropy..	0,35						
542	tBodyGyroMag.max..	0,35						
543	fBodyAcc.bandsEnergy...57.64.1	0,35						
544	tBodyAccJerk.arCoeff...X.2	0,35						
545	fBodyAcc.bandsEnergy...25.32.1	0,34						
546	fBodyAcc.bandsEnergy...49.64	0,34						
547	tBodyAccJerk.arCoeff...Z.3	0,33						
548	tGravityAccMag.arCoeff..3	0,32						
549	angle.tBodyAccJerkMean..gravityMean.	0,32						
550	fBodyAcc.iqr...Y	0,32						
551	fBodyAcc.bandsEnergy...49.64.1	0,31						
552	fBodyAccJerk.min...Z	0,31						
553	fBodyAcc.bandsEnergy...41.48.1	0,31						
554	fBodyAccJerk.entropy...Z	0,31						
555	fBodyAcc.bandsEnergy...33.40.1	0,30						
556	fBodyAcc.bandsEnergy...49.56	0,29						
557	tBodyAccMag.arCoeff..3	0,29						
558	fBodyBodyGyroMag.entropy..	0,28						