**Appendix A.**

Table A1. Complete 561 features provided by UCI-HAR database [11]

|  |  |  |  |
| --- | --- | --- | --- |
| Analytical feature | Feature no. | Function for derived features | Axis |
| tBodyAcc | [1,2,3] | mean | [X,Y,Z] |
| [4,5,6] | std | [X,Y,Z] |
| [7,8,9] | mad | [X,Y,Z] |
| [10,11,12] | max | [X,Y,Z] |
| [13,14,15] | min | [X,Y,Z] |
| [16] | sma | [-] |
| [17,18,19] | energy | [X,Y,Z] |
| [20,21,22] | iqr | [X,Y,Z] |
| [23,24,25] | entropy | [X,Y,Z] |
| [26,30,34] | arCoeff (order1) | [X,Y,Z] |
| [27,31,35] | arCoeff (order2) | [X,Y,Z] |
| [28,32,36] | arCoeff (order3) | [X,Y,Z] |
| [29,33,37] | arCoeff (order4) | [X,Y,Z] |
| [38,39,40] | correlation | [XY,XZ,YZ] |
| tGravityAcc | [41,42,43] | mean | [X,Y,Z] |
| [44,45,46] | std | [X,Y,Z] |
| [47,48,49] | mad | [X,Y,Z] |
| [50,51,52] | max | [X,Y,Z] |
| [53,54,55] | min | [X,Y,Z] |
| [56] | sma | [-] |
| [57,58,59] | energy | [X,Y,Z] |
| [60,61,62] | iqr | [X,Y,Z] |
| [63,64,65] | entropy | [X,Y,Z] |
| [66,70,74] | arCoeff (order1) | [X,Y,Z] |
| [67,71,75] | arCoeff (order2) | [X,Y,Z] |
| [68,72,76] | arCoeff (order3) | [X,Y,Z] |
| [69,73,77] | arCoeff (order4) | [X,Y,Z] |
| [78,79,80] | correlation | [XY,XZ,YZ] |
| tBodyAccJerk | [81,82,83] | mean | [X,Y,Z] |
| [84,85,86] | std | [X,Y,Z] |
| [87,88,89] | mad | [X,Y,Z] |
| [90,91,92] | max | [X,Y,Z] |
| [93,94,95] | min | [X,Y,Z] |
| [96] | sma | [-] |
| [97,98,99] | energy | [X,Y,Z] |
| [100,101,102] | iqr | [X,Y,Z] |
| [103,104,105] | entropy | [X,Y,Z] |
| [106,110,114] | arCoeff (order1) | [X,Y,Z] |
| [107,111,115] | arCoeff (order2) | [X,Y,Z] |
| [108,112,116] | arCoeff (order3) | [X,Y,Z] |
| [109,113,117] | arCoeff (order4) | [X,Y,Z] |
| [118,119,120] | correlation | [XY,XZ,YZ] |
| tBodyGyro | [121,122,123] | mean | [X,Y,Z] |
| [124,125,126] | std | [X,Y,Z] |
| [127,128,129] | mad | [X,Y,Z] |
| [130,131,132] | max | [X,Y,Z] |
| [133,134,135] | min | [X,Y,Z] |
| [136] | sma | [-] |
| [137,138,139] | energy | [X,Y,Z] |
| [140,141,142] | iqr | [X,Y,Z] |
| [143,144,145] | entropy | [X,Y,Z] |
| [146,150,154] | arCoeff (order1) | [X,Y,Z] |
| [147,151,155] | arCoeff (order2) | [X,Y,Z] |
| [148,152,156] | arCoeff (order3) | [X,Y,Z] |
| [149,153,157] | arCoeff (order4) | [X,Y,Z] |
| [158,159,160] | correlation | [XY,XZ,YZ] |
| tBodyGyroJerk | [161,162,163] | mean | [X,Y,Z] |
| [164,165,166] | std | [X,Y,Z] |
| [167,168,169] | mad | [X,Y,Z] |
| [170,171,172] | max | [X,Y,Z] |
| [173,174,175] | min | [X,Y,Z] |
| [176] | sma | [-] |
| [177,178,179] | energy | [X,Y,Z] |
| [180,181,182] | iqr | [X,Y,Z] |
| [183,184,185] | entropy | [X,Y,Z] |
| [186,190,194] | arCoeff (order1) | [X,Y,Z] |
| [187,191,195] | arCoeff (order2) | [X,Y,Z] |
| [188,192,196] | arCoeff (order3) | [X,Y,Z] |
| [189,193,197] | arCoeff (order4) | [X,Y,Z] |
| [198,199,200] | correlation | [XY,XZ,YZ] |
| tBodyAccMag | [201] | mean | [-] |
| [202] | std | [-] |
| [203] | mad | [-] |
| [204] | max | [-] |
| [205] | min | [-] |
| [206] | sma | [-] |
| [207] | energy | [-] |
| [208] | iqr | [-] |
| [209] | entropy | [-] |
| [210] | arCoeff (order1) | [-] |
| [211] | arCoeff (order2) | [-] |
| [212] | arCoeff (order3) | [-] |
| [213] | arCoeff (order4) | [-] |
| tGravityAccMag | [214] | mean | [-] |
| [215] | std | [-] |
| [216] | mad | [-] |
| [217] | max | [-] |
| [218] | min | [-] |
| [219] | sma | [-] |
| [220] | energy | [-] |
| [221] | iqr | [-] |
| [222] | entropy | [-] |
| [223] | arCoeff (order1) | [-] |
| [224] | arCoeff (order2) | [-] |
| [225] | arCoeff (order3) | [-] |
| [226] | arCoeff (order4) | [-] |
| tBodyAccJerkMag | [227] | mean | [-] |
| [228] | std | [-] |
| [229] | mad | [-] |
| [230] | max | [-] |
| [231] | min | [-] |
| [232] | sma | [-] |
| [233] | energy | [-] |
| [234] | iqr | [-] |
| [235] | entropy | [-] |
| [236] | arCoeff (order1) | [-] |
| [237] | arCoeff (order2) | [-] |
| [238] | arCoeff (order3) | [-] |
| [239] | arCoeff (order4) | [-] |
| tBodyGyroMag | [240] | mean | [-] |
| [241] | std | [-] |
| [242] | mad | [-] |
| [243] | max | [-] |
| [244] | min | [-] |
| [245] | sma | [-] |
| [246] | energy | [-] |
| [247] | iqr | [-] |
| [248] | entropy | [-] |
| [249] | arCoeff (order1) | [-] |
| [250] | arCoeff (order2) | [-] |
| [251] | arCoeff (order3) | [-] |
| [252] | arCoeff (order4) | [-] |
| tBodyGyroJerkMag | [253] | mean | [-] |
| [254] | std | [-] |
| [255] | mad | [-] |
| [256] | max | [-] |
| [257] | min | [-] |
| [258] | sma | [-] |
| [259] | energy | [-] |
| [260] | iqr | [-] |
| [261] | entropy | [-] |
| [262] | arCoeff (order1) | [-] |
| [263] | arCoeff (order2) | [-] |
| [264] | arCoeff (order3) | [-] |
| [265] | arCoeff (order4) | [-] |
| fBodyAcc | [266,267,268] | mean | [X,Y,Z] |
| [269,270,271] | std | [X,Y,Z] |
| [272,273,274] | mad | [X,Y,Z] |
| [275,276,277] | max | [X,Y,Z] |
| [278,279,280] | min | [X,Y,Z] |
| [281] | sma | [-] |
| [282,283,284] | energy | [X,Y,Z] |
| [285,286,287] | iqr | [X,Y,Z] |
| [288,289,290] | entropy | [X,Y,Z] |
| [291,292,293] | maxInds | [X,Y,Z] |
| [294,295,296] | meanFreq | [X,Y,Z] |
| [297,299,301] | skewness | [X,Y,Z] |
| [298,300,302] | kurtosis | [X,Y,Z] |
| [303,317,331] | bandsEnergy (1,8) | [X,Y,Z] |
| [304,318,332] | bandsEnergy (9,16) | [X,Y,Z] |
| [305,319,333] | bandsEnergy (17,24) | [X,Y,Z] |
| [306,320,334] | bandsEnergy (25,32) | [X,Y,Z] |
| [307,321,335] | bandsEnergy (33,40) | [X,Y,Z] |
| [308,322,336] | bandsEnergy (41,48) | [X,Y,Z] |
| [309,323,337] | bandsEnergy (49,56) | [X,Y,Z] |
| [310,324,338] | bandsEnergy (57,64) | [X,Y,Z] |
| [311,325,339] | bandsEnergy (1,16) | [X,Y,Z] |
| [312,326,340] | bandsEnergy (17,32) | [X,Y,Z] |
| [313,327,341] | bandsEnergy (33,48) | [X,Y,Z] |
| [314,328,342] | bandsEnergy (49,64) | [X,Y,Z] |
| [315,329,343] | bandsEnergy (1,24) | [X,Y,Z] |
| [316,330,344] | bandsEnergy (25,48) | [X,Y,Z] |
| fBodyAccJerk | [345,346,347] | mean | [X,Y,Z] |
| [348,349,350] | std | [X,Y,Z] |
| [351,352,353] | mad | [X,Y,Z] |
| [354,355,356] | max | [X,Y,Z] |
| [357,358,359] | min | [X,Y,Z] |
| [360] | sma | [-] |
| [361,362,363] | energy | [X,Y,Z] |
| [364,365,366] | iqr | [X,Y,Z] |
| [367,368,369] | entropy | [X,Y,Z] |
| [370,371,372] | maxInds | [X,Y,Z] |
| [373,374,375] | meanFreq | [X,Y,Z] |
| [376,378,380] | skewness | [X,Y,Z] |
| [377,379,381] | kurtosis | [X,Y,Z] |
| [382,396,410] | bandsEnergy (1,8) | [X,Y,Z] |
| [383,397,411] | bandsEnergy (9,16) | [X,Y,Z] |
| [384,398,412] | bandsEnergy (17,24) | [X,Y,Z] |
| [385,399,413] | bandsEnergy (25,32) | [X,Y,Z] |
| [386,400,414] | bandsEnergy (33,40) | [X,Y,Z] |
| [387,401,415] | bandsEnergy (41,48) | [X,Y,Z] |
| [388,402,416] | bandsEnergy (49,56) | [X,Y,Z] |
| [389,403,417] | bandsEnergy (57,64) | [X,Y,Z] |
| [390,404,418] | bandsEnergy (1,16) | [X,Y,Z] |
| [391,405,419] | bandsEnergy (17,32) | [X,Y,Z] |
| [392,406,420] | bandsEnergy (33,48) | [X,Y,Z] |
| [393,407,421] | bandsEnergy (49,64) | [X,Y,Z] |
| [394,408,422] | bandsEnergy (1,24) | [X,Y,Z] |
| [395,409,423] | bandsEnergy (25,48) | [X,Y,Z] |
| fBodyGyro | [424,425,426] | mean | [X,Y,Z] |
| [427,428,429] | std | [X,Y,Z] |
| [430,431,432] | mad | [X,Y,Z] |
| [433,434,435] | max | [X,Y,Z] |
| [436,437,438] | min | [X,Y,Z] |
| [439] | sma | [-] |
| [440,441,442] | energy | [X,Y,Z] |
| [443,444,445] | iqr | [X,Y,Z] |
| [446,447,448] | entropy | [X,Y,Z] |
| [449,450,451] | maxInds | [X,Y,Z] |
| [452,453,454] | meanFreq | [X,Y,Z] |
| [455,457,459] | skewness | [X,Y,Z] |
| [456,458,460] | kurtosis | [X,Y,Z] |
| [461,475,489] | bandsEnergy (1,8) | [X,Y,Z] |
| [462,476,490] | bandsEnergy (9,16) | [X,Y,Z] |
| [463,477,491] | bandsEnergy (17,24) | [X,Y,Z] |
| [464,478,492] | bandsEnergy (25,32) | [X,Y,Z] |
| [465,479,493] | bandsEnergy (33,40) | [X,Y,Z] |
| [466,480,494] | bandsEnergy (41,48) | [X,Y,Z] |
| [467,481,495] | bandsEnergy (49,56) | [X,Y,Z] |
| [468,482,496] | bandsEnergy (57,64) | [X,Y,Z] |
| [469,483,497] | bandsEnergy (1,16) | [X,Y,Z] |
| [470,484,498] | bandsEnergy (17,32) | [X,Y,Z] |
| [471,485,499] | bandsEnergy (33,48) | [X,Y,Z] |
| [472,486,500] | bandsEnergy (49,64) | [X,Y,Z] |
| [473,487,501] | bandsEnergy (1,24) | [X,Y,Z] |
| [474,488,502] | bandsEnergy (25,48) | [X,Y,Z] |
| fBodyAccMag | [503] | mean | [-] |
| [504] | std | [-] |
| [505] | mad | [-] |
| [506] | max | [-] |
| [507] | min | [-] |
| [508] | sma | [-] |
| [509] | energy | [-] |
| [510] | iqr | [-] |
| [511] | entropy | [-] |
| [512] | maxInds | [-] |
| [513] | meanFreq | [-] |
| [514] | skewness | [-] |
| [515] | kurtosis | [-] |
| fBodyAccJerkMag | [516] | mean | [-] |
| [517] | std | [-] |
| [518] | mad | [-] |
| [519] | max | [-] |
| [520] | min | [-] |
| [521] | sma | [-] |
| [522] | energy | [-] |
| [523] | iqr | [-] |
| [524] | entropy | [-] |
| [525] | maxInds | [-] |
| [526] | meanFreq | [-] |
| [527] | skewness | [-] |
| [528] | kurtosis | [-] |
| fBodyGyroMag | [529] | mean | [-] |
| [530] | std | [-] |
| [531] | mad | [-] |
| [532] | max | [-] |
| [533] | min | [-] |
| [534] | sma | [-] |
| [535] | energy | [-] |
| [536] | iqr | [-] |
| [537] | entropy | [-] |
| [538] | maxInds | [-] |
| [539] | meanFreq | [-] |
| [540] | skewness | [-] |
| [541] | kurtosis | [-] |
| fBodyGyroJerkMag | [542] | mean | [-] |
| [543] | std | [-] |
| [544] | mad | [-] |
| [545] | max | [-] |
| [546] | min | [-] |
| [547] | sma | [-] |
| [548] | energy | [-] |
| [549] | iqr | [-] |
| [550] | entropy | [-] |
| [551] | maxInds | [-] |
| [552] | meanFreq | [-] |
| [553] | skewness | [-] |
| [554] | kurtosis | [-] |
| angle  between  two components | [555] | tBodyAccMean, gravity | [-] |
| [556] | tBodyAccJerkMean, gravityMean | [-] |
| [557] | tBodyGyroMean, gravityMean | [-] |
| [558] | tBodyGyroJerkMean, gravityMean | [-] |
| [559] | X, gravityMean | [-] |
| [560] | Y, gravityMean | [-] |
| [561] | Z, gravityMean | [-] |
| Note: function for derived features  mean(): mean value std(): standard deviation  mad(): median absolute deviation max(): largest value in array  min(): smallest value in array sma(): signal magnitude area  iqr(): interquartile range entropy(): signal entropy  energy(): energy measure. Sum of the squares divided by the number of values.  arCoeff(): auto-regression 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 in the 64 bins of the FFT of each window.  angle(): angle between to vectors. | | | |

Table A2. Feature selection due to recursive feature elimination (RFE) with SVM and RF estimator

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Estimator | RFE+SVM | | | RFE+RF | | |
| Feature no. | 120 feat. | 110 feat. | 100 feat. | 120 feat. | 110 feat. | 100 feat. |
| [4,5,6] | [v,v,v] | [v,v,v] | [v,v,v] | [v,-,-] | [v,-,-] | [v,-,-] |
| [7,8,9] | [v,-,v] | [v,-,-] | [v,-,-] | [v,-,-] | [v,-,-] | [v,-,-] |
| [10,11,12] | [v,-,v] | [v,-,-] | [v,-,-] | [v,-,-] | [v,-,-] | [v,-,-] |
| [16] | [v] | [v] | [v] |  |  |  |
| [17,18,19] |  |  |  | [v,-,-] | [v,-,-] | [v,-,-] |
| [20,21,22] | [v,-,-] | [v,-,-] | [v,-,-] |  |  |  |
| [23,24,25] |  |  |  | [v,-,-] | [v,-,-] |  |
| [26,30,34] | [v,-,-] | [v,-,-] | [v,-,-] |  |  |  |
| [27,31,35] | [v,-,-] | [v,-,-] | [v,-,-] |  |  |  |
| [38,39,40] |  |  |  | [v,v,v] | [v,-,-] | [v,-,-] |
| [41,42,43] | [v,-,v] | [v,-,v] | [v,-,v] | [v,v,v] | [v,v,v] | [v,v,v] |
| [44,45,46] | [-,v,-] | [-,v,-] | [-,v,-] |  |  |  |
| [47,48,49] | [v,-,-] | [v,-,-] | [v,-,-] |  |  |  |
| [50,51,52] | [v,-,-] |  |  | [v,v,v] | [v,v,v] | [v,v,v] |
| [53,54,55] | [v,v,-] | [v,v,-] | [v,v,-] | [v,v,v] | [v,v,v] | [v,v,v] |
| [56] |  |  |  | [v] | [v] | [v] |
| [57,58,59] | [v,v,v] | [v,v,v] | [v,v,v] | [v,v,v] | [v,v,v] | [v,v,v] |
| [60,61,62] | [-,-,v] | [-,-,v] | [-,-,v] |  |  |  |
| [63,64,65] |  |  |  | [v,v,-] | [v,v,-] | [-,v,-] |
| [66,70,74] | [v,v,-] | [v,v,-] | [v,v,-] | [v,v,v] | [v,v,v] | [v,v,v] |
| [67,71,75] |  |  |  | [v,v,v] | [v,v,v] | [v,v,v] |
| [68,72,76] | [v,-,-] | [v,-,-] | [v,-,-] | [v,v,v] | [v,v,v] | [v,v,v] |
| [69,73,77] | [-,v,-] | [-,v,-] | [-,v,-] | [v,v,v] | [v,v,v] | [v,v,v] |
| [78,79,80] |  |  |  | [v,-,-] | [v,-,-] | [v,-,-] |
| [84,85,86] |  |  |  | [v,-,-] | [v,-,-] | [v,-,-] |
| [87,88,89] |  |  |  | [v,-,-] | [v,-,-] | [v,-,-] |
| [90,91,92] |  |  |  | [v,-,-] | [v,-,-] | [v,-,-] |
| [96] |  |  |  | [v] | [v] |  |
| [97,98,99] | [-,-,v] | [-,-,v] | [-,-,v] | [v,-,-] | [v,-,-] | [v,-,-] |
| [103,104,105] | [v,-,v] | [v,-,v] | [v,-,v] | [v,-,-] | [-,-,v] | [v,-,-] |
| [124,125,126] | [-,-,v] | [-,-,v] |  | [v,-,-] | [v,v,-] | [v,-,-] |
| [127,128,129] | [-,-,v] | [-,-,v] | [-,-,v] | [v,v,-] | [v,-,-] | [-,v,-] |
| [130,131,132] | [-,v,-] | [-,v,-] | [-,v,-] | [v,-,-] | [v,-,-] | [v,-,-] |
| [133,134,135] |  |  |  | [v,-,-] | [v,-,-] | [v,-,-] |
| [136] | [v] | [v] | [v] |  |  |  |
| [137,138,139] | [-,-,v] | [-,-,v] | [-,-,v] | [-,v,-] | [-,-,v] | [-,v,-] |
| [140,141,142] |  |  |  | [v,v,v] | [v,-,-] | [v,-,-] |
| [143,144,145] |  |  |  | [v,-,-] | [v,-,-] | [v,-,-] |
| [146,150,154] | [v,-,-] | [v,-,-] | [v,-,-] |  |  |  |
| [147,151,155] | [v,-,-] | [v,-,-] | [v,-,-] |  |  |  |
| [158,159,160] |  |  |  | [-,-,v] | [-,-,v] | [-,-,v] |
| [164,165,166] | [v,-,-] | [v,-,-] | [v,-,-] | [v,-,-] | [v,-,-] | [v,-,-] |
| [167,168,169] | [v,v,v] | [v,v,v] | [v,v,v] | [v,-,-] | [v,-,v] | [v,-,v] |
| [170,171,172] | [-,v,-] | [-,v,-] | [-,v,-] |  |  |  |
| [177,178,179] | [v,v,v] | [v,v,v] | [v,v,v] | [v,-,-] |  | [v,-,-] |
| [180,181,182] |  |  |  | [v,-,-] | [v,-,-] | [v,-,-] |
| [183,184,185] | [v,-,-] | [v,-,-] | [v,-,-] |  |  |  |
| [186,190,194] | [v,-,-] | [v,-,-] | [v,-,-] | [v,-,-] |  |  |
| [198,199,200] |  |  |  | [v,-,-] |  |  |
| [201] | [v] | [v] | [v] |  |  |  |
| [202] | [v] | [v] | [v] | [v] | [v] | [v] |
| [203] |  |  |  | [v] | [v] | [v] |
| [204] |  |  |  | [v] |  |  |
| [206] | [v] | [v] | [v] |  |  |  |
| [207] | [v] | [v] | [v] |  |  |  |
| [208] | [v] | [v] | [v] |  |  |  |
| [210] |  |  |  | [v] | [v] | [v] |
| [211] |  |  |  | [v] |  |  |
| [214] | [v] | [v] | [v] |  |  |  |
| [215] | [v] | [v] | [v] | [v] | [v] | [v] |
| [216] |  |  |  | [v] | [v] | [v] |
| [219] | [v] | [v] | [v] |  |  |  |
| [220] | [v] | [v] | [v] |  |  |  |
| [223] |  |  |  | [v] | [v] | [v] |
| [224] |  |  |  | [v] | [v] | [v] |
| [227] | [v] | [v] | [v] |  | [v] | [v] |
| [229] | [v] | [v] | [v] | [v] | [v] | [v] |
| [232] | [v] | [v] | [v] | [v] | [v] |  |
| [233] | [v] | [v] | [v] |  | [v] | [v] |
| [234] |  |  |  | [v] | [v] | [v] |
| [235] |  |  |  | [v] | [v] |  |
| [241] | [v] | [v] | [v] |  |  |  |
| [242] | [v] | [v] | [v] |  |  |  |
| [243] | [v] | [v] | [v] |  |  |  |
| [250] | [v] | [v] |  |  |  |  |
| [251] | [v] | [v] |  |  |  |  |
| [252] | [v] | [v] |  |  |  |  |
| [259] | [v] | [v] | [v] |  |  |  |
| [262] | [v] | [v] | [v] |  |  |  |
| [263] | [v] | [v] | [v] |  |  |  |
| [264] | [v] | [v] | [v] |  |  |  |
| [265] | [v] | [v] | [v] |  |  |  |
| [266,267,268] | [-,v,-] | [-,v,-] | [-,v,-] | [v,-,-] | [v,-,-] | [v,-,-] |
| [269,270,271] | [-,v,v] | [-,v,v] | [-,v,v] | [v,-,-] | [v,-,-] | [v,-,-] |
| [272,273,274] | [v,-,-] | [v,-,-] | [v,-,-] | [v,-,-] | [v,-,-] | [v,-,-] |
| [275,276,277] |  |  |  | [v,-,-] | [v,-,-] | [v,-,-] |
| [282,283,284] | [v,v,v] | [v,v,v] | [v,v,v] | [v,-,-] | [v,-,-] | [v,-,-] |
| [294,295,296] |  |  |  | [-,-,v] | [-,-,v] |  |
| [297,299,301] | [-,-,v] | [-,-,v] | [-,-,v] |  |  |  |
| [298,300,302] | [-,-,v] | [-,-,v] | [-,-,v] |  |  |  |
| [303,317,331] | [v,-,-] |  |  | [v,v,-] | [v,-,-] | [v,-,-] |
| [305,319,333] | [-,-,v] | [-,-,v] | [-,-,v] |  |  |  |
| [311,325,339] | [v,v,v] | [v,v,v] | [v,v,v] | [v,-,-] | [v,-,-] | [v,-,-] |
| [315,329,343] |  |  |  | [v,-,-] | [v,-,-] | [v,-,-] |
| [345,346,347] | [-,-,v] | [-,-,v] | [-,-,v] |  | [v,-,-] |  |
| [348,349,350] | [v,-,-] | [v,-,-] | [v,-,-] | [v,-,-] | [v,-,-] | [v,-,-] |
| [351,352,353] |  |  |  |  |  | [v,-,-] |
| [354,355,356] |  |  |  |  | [v,-,-] |  |
| [360] |  |  |  | [v] |  |  |
| [361,362,363] | [-,-,v] | [-,-,v] | [-,-,v] | [v,-,-] |  | [v,-,-] |
| [367,368,369] |  |  |  |  | [v,-,-] |  |
| [370,371,372] |  |  |  | [v,-,v] | [v,-,v] |  |
| [382,396,410] | [-,v,-] | [-,v,-] | [-,v,-] | [v,-,v] | [v,-,-] | [v,-,-] |
| [383,397,411] | [v,-,-] |  |  |  |  |  |
| [384,398,412] | [v,-,-] |  |  |  |  |  |
| [390,404,418] | [-,v,-] | [-,v,-] | [-,v,-] | [v,-,-] | [v,-,-] | [v,-,-] |
| [391,405,419] | [v,v,-] | [v,v,-] | [v,v,-] | [-,-,v] |  | [-,-,v] |
| [394,408,422] | [-,-,v] | [-,-,v] | [-,-,v] | [v,-,-] | [v,-,-] | [v,-,-] |
| [424,425,426] |  |  |  | [v,-,-] | [v,-,-] | [v,-,-] |
| [427,428,429] | [-,-,v] | [-,-,v] | [-,-,v] | [v,-,-] | [v,-,-] | [v,-,-] |
| [430,431,432] | [v,-,-] | [v,-,-] | [v,-,-] | [v,v,-] | [v,-,-] | [v,-,-] |
| [433,434,435] |  |  |  | [v,v,v] | [v,v,-] | [v,v,-] |
| [440,441,442] |  |  |  | [v,v,-] | [-,v,-] | [v,-,-] |
| [443,444,445] | [-,-,v] |  |  |  |  |  |
| [446,447,448] | [v,-,-] | [v,-,-] |  |  | [v,-,-] | [v,-,-] |
| [449,450,451] |  |  |  | [v,-,v] | [v,v,v] | [v,-,v] |
| [452,453,454] |  |  |  | [v,-,-] | [v,-,-] | [v,-,-] |
| [456,458,460] |  |  |  | [-,-,v] |  |  |
| [461,475,489] | [v,-,-] | [v,-,-] | [v,-,-] | [v,v,-] | [v,-,-] | [v,v,-] |
| [462,476,490] | [v,-,v] | [-,-,v] | [-,-,v] | [v,-,-] | [v,-,-] | [v,-,-] |
| [463,477,491] |  |  |  | [-,-,v] |  |  |
| [464,478,492] | [-,v,-] |  |  |  |  |  |
| [469,483,497] | [v,-,-] | [v,-,-] | [v,-,-] | [v,-,-] | [v,v,-] | [v,-,-] |
| [473,487,501] |  |  |  |  | [v,-,-] | [v,-,-] |
| [503] | [v] | [v] |  | [v] | [v] | [v] |
| [504] | [v] | [v] |  | [v] | [v] | [v] |
| [505] | [v] | [v] |  | [v] | [v] | [v] |
| [508] | [v] | [v] |  | [v] | [v] | [v] |
| [509] | [v] | [v] | [v] | [v] | [v] | [v] |
| [510] | [v] |  |  |  |  |  |
| [513] |  |  |  | [v] | [v] | [v] |
| [516] | [v] | [v] | [v] |  |  |  |
| [517] | [v] | [v] | [v] |  | [v] |  |
| [521] | [v] | [v] | [v] |  |  |  |
| [522] | [v] | [v] | [v] |  |  |  |
| [524] | [v] | [v] |  |  |  |  |
| [539] |  |  |  | [v] |  |  |
| [542] | [v] | [v] | [v] |  |  |  |
| [547] | [v] | [v] | [v] |  |  |  |
| [550] | [v] | [v] | [v] |  |  |  |
| [559] | [v] | [v] | [v] | [v] | [v] | [v] |
| [560] | [v] | [v] | [v] | [v] | [v] | [v] |
| [561] | [v] | [v] | [v] | [v] | [v] | [v] |
| Note: the symbol 'v' and '-' represent the correspondent feature no. defined in Table A1 is selected and not selected, respectively. | | | | | | |

Table A3. Analytical features and functions for derived features due to MHEALTH and WISDM [12,13]

|  |  |  |
| --- | --- | --- |
| **MHEALTH database** | | |
| Feature domain | Analytical feature | Function for derived features |
| Time | tChestAcc  tArmAcc, tAnkleAcc  tArmGyro, tAnkleGyro  tArmMagnet, tAnkleMagnet | Produce vectors on [X,Y,Z] axes: mean(), std(), mad(), max(), min(), energy(), iqr(),kurtosis() |
| Frequency | fChestAcc  fArmAcc, fAnkleAcc  fArmGyro, fAnkleGyro  fArmMagnet, fAnkleMagnet |
| Notes: The MHEALTH’s analytical features named with Acc, Gyro, and Magnet mean measuring acceleration, angular velocity, and magnetic field, respectively. All time-domain features in were also converted to frequency domain through fast Fourier transformation (FFT).  Descriptions of functions for derived features are detailed in Table A1.  A total of 168 features on [X, Y, Z] axes can be obtained in each domain. | | |
| **WISDM database** | | |
| Feature domain | Analytical feature | Function for derived features |
| Time | tPhoneAcc, tPhoneGyro, tWatchAcc, tWatchGyro | Produce vectors on [X,Y,Z] axes: mean(), std(), mad(), max(), min(), energy(), iqr(),kurtosis() |
| Number of segment groups:    Group (a): smartphone’s acceleration and angular velocity (i.e, tPhoneAcc & tPhoneGyro)  Group (b): smartwatch’s acceleration and angular velocity (i.e, tWatchAcc & tWatchGyro)  Group (c): acceleration measured by smartphone and smartwatch (i.e, tPhoneAcc & tWatchAcc)  Group (d): angular velocity measured by smartphone and smartwatch (i.e, tPhoneGyro & tWatchGyro)  Activity labels: label 0: Walking; label 1: Jogging; label 2: Climbing Stairs; label 3: Sitting;  label 4: Standing; label 5: Typing; label 6: Brushing Teeth; label 7: Eating Soup; label 8: Eating Chips; label 9: Eating Pasta; label 10: Drinking from Cup; label 11: Eating Sandwich; label 12: Kicking Soccer Ball; label 13: Playing Catch with Tennis Ball; label 14: Dribbling Basketball; label 15: Writing;  label 16: Clapping; label 17: Folding Clothes | | |
| Notes:   * The WISDM’s analytical features named with Acc and Gyro mean acceleration and angular velocity, respectively, which were measure by smartphone (PHONE) and smartwatch (WATCH). * Descriptions of functions for derived features are detailed in Table A1. * G\L: Group\Label * A total of 48 features on [X, Y, Z] axes can be obtained in time domain. | | |

Table A4. Confusion matrixes of SVM and RF models trained by UCI-HAR’s optimal features due to RFE+RF

|  |  |
| --- | --- |
| Part (a) 100 features | |
| SVM model, accuracy=0.937 | RF model, accuracy=0.9 |
| Part (b) 110 features | |
| SVM model, accuracy=0.95 | RF model, accuracy=0.905 |
| Part (c) 120 features | |
| SVM model, accuracy=0.946 | RF model, accuracy=0.902 |
| Notes: T\P: True\Prediction; rec.: recall; prec.:precision; f1: f1-score | |

Table A5. Confusion matrixes of HAR models trained by UCI-HAR for label-oriented analysis

|  |  |
| --- | --- |
| 1dCNN model, accuracy=0.979 | ANFIS model, accuracy=0.954 |
| SVM model, accuracy=0.975 | RF model, accuracy=0.963 |
| Notes: T\P: True\Prediction; rec.: recall; prec.:precision; f1: f1-score  The ANFIS, RF, and SVM models were trained by 100 optimal features due to RFE+SVM | |

Table A6. Confusion matrixes of DL-based and ML-based HAR models trained by WISDM

|  |
| --- |
| 1dCNN model trained by datasets due to the accelerometers of smartphone and smartwatch, accuracy = 0.914 |
| RF model trained by datasets due to the accelerometers of smartphone and smartwatch, accuracy = 0.873 |
| 1dCNN model trained by datasets due to the gyroscopes of smartphone and smartwatch, accuracy = 0.831 |
| RF model trained by datasets due to the gyroscopes of smartphone and smartwatch,  accuracy = 0.724 |
| 1dCNN model trained by datasets due to the smartphone’s accelerometer and gyroscope, accuracy = 0.748 |
| RF model trained by datasets due to the smartphone’s accelerometer and gyroscope,  accuracy = 0.793 |
| 1dCNN model trained by datasets due to the smartwatch’s accelerometer and gyroscope,  accuracy = 0.89 |
| RF model trained by datasets due to the smartwatch’s accelerometer and gyroscope, accuracy = 0.808 |
| Notes: T\P: True\Prediction; rec.: recall; prec.:precision; f1: f1-score.  The RF model, with a ratio of 7:3 for training and testing data, used a total of 48 three-axis time-domain features derived by the functions of "mean", "std", "mad", "max", "min", "energy", "iqr", "kurtosis" as shown in Table A1.  Activity labels: label 0: Walking; label 1: Jogging; label 2: Climbing Stairs; label 3: Sitting; label 4: Standing; label 5: Typing; label 6: Brushing Teeth; label 7: Eating Soup; label 8: Eating Chips; label 9: Eating Pasta; label 10: Drinking from Cup; label 11: Eating Sandwich; label 12: Kicking Soccer Ball; label 13: Playing Catch with Tennis Ball; label 14: Dribbling Basketball; label 15: Writing; label 16: Clapping; label 17: Folding Clothes |

Table A7. Approach summary of accuracies due to the proposed HAR models and the past studies

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Datasets** | **References** | **Input data** | **Models** | **Accuracy** |
| UCI-HAR | our current study | 561 features | SVM | 0.958 |
| 561 features | RF | 0.917 |
| 100 features by RFE+SVM | SVM | 0.939 |
| 110 features by RFE+SVM | SVM | 0.939 |
| 120 features by RFE+SVM | SVM | 0.946 |
| 100 features by RFE+SVM | RF | 0.888 |
| 110 features by RFE+SVM | RF | 0.892 |
| 120 features by RFE+SVM | RF | 0.895 |
| 100 features by RFE+SVM | ANFIS | 0.898 |
| 110 features by RFE+SVM | ANFIS | 0.914 |
| 120 features by RFE+SVM | ANFIS | 0.905 |
| raw data | 1dCNN | 0.925 |
| [34] (our previous study) | raw data | hybrid CNNs | 0.96 |
| [12] | 561 features | SVM | 0.96 |
| [35] | raw data | DCNN-LSTM | 0.999 |
| [11] | raw data with FFT | 2dCNN | 0.9569 |
| MHEALTH | our current study | raw data | 1dCNN | 1 |
| 336 features(\*) | RF | 0.998 |
| 336 features(\*) | SVM | 0.997 |
| 84 features(\*\*) | ANFIS | 0.965 |
| [11] | raw data with FFT | 2dCNN | 0.9988 |
| WISDM | our current study | accelerometers raw data | 1dCNN | 0.914 |
| accelerometers 48 features(\*) | RF | 0.873 |
| gyroscopes raw data | 1dCNN | 0.831 |
| gyroscopes 48 features(\*) | RF | 0.724 |
| smartphone raw data | 1dCNN | 0.748 |
| smartphone 48 features(\*) | RF | 0.793 |
| smartwatch raw data | 1dCNN | 0.89 |
| smartwatch 48 features(\*) | RF | 0.808 |
| [35] | raw data | DCNN-LSTM | 0.999 |
| [41] | smartwatch raw data | ConvLSTM | 0.841 |
| smartwatch raw data | RF | 0.616 |
| smartphone raw data | ConvLSTM | 0.849 |
| smartphone raw data | RF | 0.754 |
| Note: (\*) Derived by mean, std, mad, max, min, energy, iqr, kt functions; (\*\*) Derived by mean, std, min, iqr functions | | | | |