### Bioharness and In-car sensor Features

#### Time-domain Features

"abs energy" -

"absolute\_sum\_of\_changes" -

"sample\_entropy"- using the chebychev norm [Madalena Costa, Ary Goldberger, CK Peng. Multiscale entropy analysis of biological signals]

"binned\_entropy" -

where is the percentage of samples in bin:.

"sum Values" =

"median" – median value

"mean" -

"variance" -

"maximum" -

"minimum" -

"kurtosis" (Fisher) -

"skewness" -

"standard deviation" -

"variance greater than standard deviation" -

"count\_above\_mean" – count of variables greater than

"count\_below\_mean" – count of variables less than

"interquartile range" - [Upton, Graham; Cook, Ian (1996). Understanding Statistics. Oxford University Press. p. 55. ISBN 0-19-914391-9.]

"first\_location\_of\_maximum" – first location of the maximum value of

"last\_location\_of\_maximum" – last location of the maximum value of

"first\_location\_of\_minimum" – first location of the minimum value of

"last\_location\_of\_minimum" – last location of the minimum value of

"median\_absolute\_deviation" -

"norm\_squared\_entropy" -

"sig\_energy" -

"num\_zero\_crossings" – Number of zero crossing occurances.

#### Frequency Domain Features

"max\_fft\_mag\_value" - Maximum value of the FFT magnitude

"max\_fft\_rel\_mag\_index" – The relative index (in terms of the length of the magnitude vector) of the maximum fft value.

"max\_fft\_mag\_freq" – Frequency value of the magnitude peak.

"e\_fft\_bin\_0" - e\_fft\_bin\_4 – Five energy bins are calculated across the f spectrum

"fft\_mag\_energy" – total magnitude spectrum energy

"mean\_fft\_mag" – mean of magnitude spectrum

"std\_fft\_mag" – Standard Deviation of the magnitude spectrum

"mad\_fft\_mag" - Median Absolute Deviation

"quartile\_fft\_mag" – Interquartile range

"s\_entropy\_fft\_mag" – sample entropy using the chebychev norm [Madalena Costa, Ary Goldberger, CK Peng. Multiscale entropy analysis of biological signals]

"sh\_entropy\_fft\_mag" – shannon entropy

"sh\_sq\_entropy\_fft\_mag" – square of the above

"f\_mean\_fft\_mag" – mean of the magnitude spectrum

"skew\_fft\_mag" – skewness of fft magnitude

"kurtosis\_fft\_mag" – Fisher kurtosis of fft magnitude

### CAN Data Features

#### TD Signals

See Time Domain Features and Frequency Domain Features above

#### Acc Signals

See Time Domain Single Axial Component Features

See Frequency Domain Single Axial Component Features

#### Discrete Signals

See Time Domain Features above

### HRV Features.

#### Time Domain HRV Features

“mean\_nni” - R-R interval mean.

“sdnn” – Standard deviation of -R intervals.

“sdsd” - Standard deviation of differences between adjacent RR-intervals.

“nni\_1” - Number of interval differences of successive RR-intervals greater than 1 ms

“nni\_2“ – nni greater than 2 ms

“nni\_5“– nni greater than 5 ms

“nni\_10“– nni greater than 10 ms

“nni\_20“– nni greater than 20 ms

“nni\_50“– nni greater than 50 ms

“pnni\_1” - nni\_1 divided by the total number of RR-intervals

“pnni\_2” - nni\_2 divided by the total number of RR-intervals

“pnni\_5”

“pnni\_10”

“pnni\_20”

“pnni\_50”

“rmssd” - The square root of the mean of the sum of the squares of differences between adjacent NN-intervals.

“median\_nni” - Median Absolute values of the successive differences between the RR-intervals.

“range\_nni” - Difference between the maximum and minimum nn\_interval.

“cvsd” - Coefficient of variation of successive differences equal to the rmssd divided by mean\_nni.

“cvnni” - Coefficient of variation, .

“Mean\_hr” – Mean heart rate.

"max\_hr" - Max heart rate.

"min\_hr" - Min heart rate.

"std\_hr" - Standard deviation of heart rate.

"shannon\_e" – Shannon entropy.

“sh\_sq\_energy" - Shannon squared entropy.

"log\_mag" -

#### Frequency Domain Features

“lf” - Frequency content between 0.04 and 0.15 Hz

“hf” - Frequency content between 0.15 and 0.4 Hz

“lf\_hf\_ratio” -

“lfnu” -

“hfnu” -

- frequency content below 0.04Hz

“total\_power” -

#### Bi-spectrum features

The third moment sequence of a signal is equivalent to the third-order cumulant sequence:

Where denotes the expectation function. The two-dimensional Fourier transform of yields a bispectrum:

with the condition:|𝜔1|,|𝜔2|≤𝜋 for 𝜔=2𝜋𝑓 [A. Parsi, D. O’Loughlin, M. Glavin and E. Jones, "Prediction of Sudden Cardiac Death in Implantable Cardioverter Defibrillators: A Review and Comparative Study of Heart Rate Variability Features," in IEEE Reviews in Biomedical Engineering, vol. 13, pp. 5-16, 2020, doi: 10.1109/RBME.2019.2912313.]

"mean\_LL" Mean value of the LL Region Of Interest (ROI) of the bispectrum.

"mean\_LH" - Mean value of the LH ROI.

"mean\_HH" - Mean value of the HH ROI.

"mean\_ROI" - Mean value of the total frequency ROI.

"pBand\_LL" – Integration of the LL bispectrum periodogram, to yield band power.

"pBand\_LH"

"pBand\_HH"

"pBand\_ROI"

"log\_mag\_LL" – Log magnitude of the LL bispectrum.

"log\_mag\_LH"

"log\_mag\_HH"

"log\_mag\_roi”

"D\_log\_mag\_LL" – Log magnitude of the diagonal of the LL bispectrum.

"D\_log\_mag\_LH"

"D\_log\_mag\_HH"

"D\_log\_mag\_roi"

"wc\_x\_LL" - Weight centre of x axis frequency component of the LL bispectrum

"wc\_x\_LH"

"wc\_x\_HH"

"wc\_x\_roi"

"wc\_y\_LL” - Weight centre of y axis frequency component of the LL bispectrum

"wc\_y\_LH"

"wc\_y\_HH”

"wc\_y\_roi”

#### Poincare Features

Poincare Plot – [CITE – Ashkan]

“sd1” - Standard deviation of projection of the Poincaré plot on the line perpendicular to the line of identity.

“sd2” - Standard deviation of the projection of the Poincaré plot on the line of identity (y=x).

“ratio\_sd2\_sd1” -

"area" -

“dm\_sd1” – Standard deviation of

“dm\_sd2” - Standard deviation of

“dm\_ratio\_sd2\_sd1” -

"dm\_area" -

#### Non-linear Features

“csi”: Cardiac Sympathetic Index.

“cvi” - Cadiac Vagal Index.,

[Using Lorenz plot and Cardiac Sympathetic Index of heart rate variability for detecting \

seizures for patients with epilepsy, Jesper Jeppesen et al, 2014]

### Tri-axial Accelerometer Features

Signal model -

#### Time Domain Tri-axial Component Features

"sma" – Signal Magnitude Area.

"corr\_x\_y" - Pearson correlation coefficient between two vectors and .

"corr\_x\_z" - Pearson correlation coefficient between and .

"corr\_y\_z” - Pearson correlation coefficient between and.

"angle\_mnbody\_mngrav" – Angle in radians between and **.**

"angle\_mnjerkbody\_mngrav" – Angle in radians between and **.**

"angle\_mnjerkgrav\_mnbody" – Angle in radians between and **.**

“angle\_bodyx\_mngrav” – Angle in radians between and **.**

"angle\_bodyy\_mngrav" – Angle in radians between and **.**

"angle\_bodyz\_mngrav" – Angle in radians between and **.**

"angle\_gravx\_mnbody" – Angle in radians between and **.**

"angle\_gravy\_mnbody" – Angle in radians between and **.**

"angle\_gravz\_mnbody" - Angle in radians between and **.**

#### Time Domain Single Axial Component Features

All the following calculated for each componenet of a tri-axial signal, e.g. for :

"mean\_x" – Mean of

"std\_x" – Standard deviation of

"mad\_x" – Median Absolute Deviation of . .

"max\_x" – Max of

"min\_x" – Min of

"energy\_x" -

"quantile\_x" - interquartile range of - [Upton, Graham; Cook, Ian (1996). Understanding Statistics. Oxford University Press. p. 55. ISBN 0-19-914391-9.].

"s\_entropy\_x" - Calculates the sample entropy of degree m of using the chebychev norm. Madalena Costa, Ary Goldberger, CK Peng. Multiscale entropy analysis of biological signals.

"sh\_entropy\_x" -

Where is represented bythe normalised form of in a range between 1 and 2 as follows:

Where and .

"bin\_entropy\_x" – Binned Entropy of -

where is the percentage of samples in bin:.

"corr\_x\_y" - Pearson correlation coefficient between two vectors and .

"corr\_x\_z" - Pearson correlation coefficient between and .

"corr\_y\_z” - Pearson correlation coefficient between and.

“skew\_x” -

“kurtosis\_x” -

“absolute\_sum\_of\_changes\_x” -

“sum\_values\_x” -

“variance\_x” -

“variance\_gtr\_sd\_x” -

“count\_above\_mean\_x” - Count of values of greater than

“count\_below\_mean\_x”- Count of values of less than

“first\_loc\_max\_x” - first index occurance of the maximum of , index returned relative to length of .

“first\_loc\_min\_x” - first index occurance of the minimum of , relative to length of .

"zcc\_x" – Zero crossing count of .

Repeat for and .

#### Frequency Domain Single Axial Component Features

All the following calculated for :

“max\_fft\_mag\_value” – Maximum of

“max\_fft\_rel\_mag\_index” – Relative index location of the maximum of

“max\_fft\_mag\_freq” – Frequency of the of the maximum of

“fft\_mag\_energy” -

“mean\_fft\_mag” –

“std\_fft\_mag” – Standard Deviation of

“mad\_fft\_mag” – Median Absolute Deviation of

“min\_fft\_mag” -

“quartile\_fft\_mag” – Interquartile range of

“s\_entropy\_fft\_mag” – Sample entropy of

“sh\_entropy\_fft\_mag” – Shannon Entropy of

“f\_mean\_fft\_mag”- Frequency location of

“skew\_fft\_mag” -

“kurtosis\_fft\_mag” -