Biofeedback: Analysing Impact of Energy Utilization & Energy Recovery States on Wellbeing

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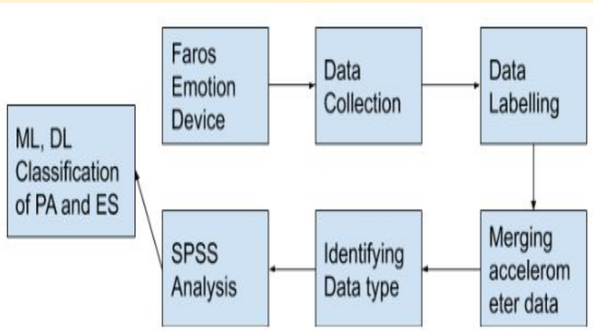
Abstract

The main goal is to determine the time duration to which the user is exposed to stressful activity. Including visualization of the most contributing parameters like PNS and SNS. This is carried on the 24 hours ECG Data recording of 40 individuals, using Bittium Faros 180 sensor.

Here, we would analyse the effect of stress in the Autonomic Nervous System (ANS) by closely working on 41 HRV parameters and 3 tri-axial Accelerometer parameters.

Followed by Machine Learning and Deep Learning approaches towards classification aming to accurately differentiate ES (Emotional Stress) from PA(Physical Activity). Combining above activities causes consumption of energy. SMOTE method has been used to solve the problem of overfitting due to imbalance in instances of each class. Using Classification Angle Framework we will optain the percentage distribution of both energy recovery and stress inducing states. At the end with the help of visualization we would observe a case of stage 4 cancer patient, comparing it with a healthy human.

Process Flow



This shows the flow of process

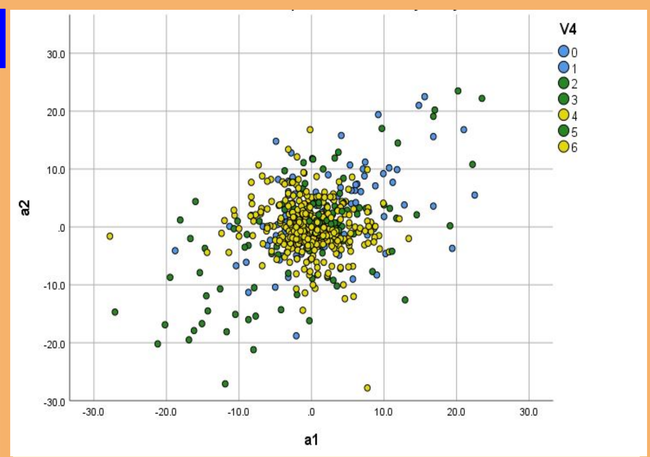
Statistical Data Analysis

Results of Normalization Test, Homogeneity Test, and Skewness- Kurtosis Test:

- A Shapiro-Wilk's test (p>0.05) and visual inspection of their histograms, normal Q-Q plots and box-plots show that the HRV parameters are approximately normally distributed.
- The Skewness and Kurtosis are in range -1.96 to +1.96 . But, Leven's p = (value is <0.05) thereby rejecting the null hypothesis of Homogeneity Test.
- If any one of the tests fail then ANOVA cannot be applied.
- Instead Kruskal-Wallis Test is used for non-parametric data.

Parameter	TEST	P-Value	Difference as per Bonferroni correction (Pairwise Comparison)	Signi-ficance
PNS index TINN pNNxx Mean RR STDRR Mean HR Min HR Max HR NNxx EE Activity SD2/SD1 EDR DFA1 DFA2 Load	Kruskal-Wallis Test	<0.0001	All have p -value <0.05	Best for differenti ating all the mentione d activities

This Table Highlights parameters which stand out for better classification



This figure shows the second-order difference(SODP) plot employed in the classification framework using a three-point forward approximation for the HRV series.

Here, x(n) is a point in HRV time series data at any time n(min).

a1 = 4x(n+1) - 3x(n) - x(n+2)

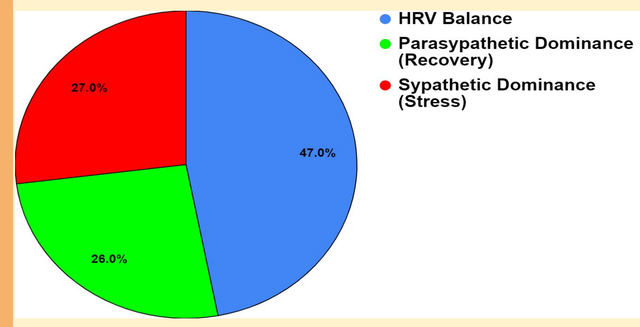
a2 = 4x(n+2) - 3x(n+1) - x(n+3)

Quadrant 1 - Parasympathetic Dominance (Recovery)

Quadrant 2-4 - HRV Balance

Quadrant 3 - Sympathetic Dominance (Stress)

Colour	Blue	Green	Yellow
Activity	Static Activities (Standing, Sitting)	Dynamic Activities (Cycling, Walking, Running)	Resting Activities (Sleep, Humming)



This figure represents the percentage of stress and recovery based classification.

Conclusion and Results

Method	Without Accelero meter	With Accelero meter	Highest Contributing Parameter
K - Means	85%	91.5%	Mean HR
CHAID	83.3%	83.5%	-
CRT	85%	85%	-
ANN	88%	87.8%	STDRR

Further after using SMOTE as preprocessing step: Random Forest algorithm has been used for the classification of PA and ES after balancing the count to obtain 98.44% accuracy.

Future Enhancements

- We have 270 hours of supine data, which can be divided into subcategories of REM (Rapid Eye Movement) and NREM (Non Rapid Eye Movement).
- PA (Physical Activity) can be further classified into Static (Standing, sitting) and Non-static (Running, Ascending, walking) activities by calculating from a vertical axis: sin-1 (x1/(√((x2-x1)2+ (y2-y1)2 + (z2-z1)2)).
- A Mobile App Development for easy communication between client and company. ANN and CRT best used in Anomaly Detection for T1 Diabetes Patients.

References

Adjei, T., von Rosenberg, W., & Mandic, D. P. (2019). The classA framework: HRV based assessment of SNS and PNS dynamics without LF-HF controversies. *Frontiers in physiology*, *10*, 505.