Multiclass Classification and Feature Analysis of FTM Drawing Tasks in a Digital Assessment of Tremor

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Introduction

- Essential tremor (ET) is degenerative neurological condition that most commonly results in uncontrollable rhythmic motions of the upper limb. The early diagnosis of ET and the tracking of symptom progression over time is required for the constructive treatment of the disease.
- Fahn-Tolosa-Marin (FTM) drawing tasks, such as tracing an Archimedes spiral or staying in between two lines, are well-grounded clinical techniques for evaluating ET symptoms.
- Although there are existing computational methods for the quantification of ET derived from the Archimedes Spirals [1] [2], development of a straightforward system able to precisely classify the drawing tasks as well as different severity levels of ET is still a topic of study.
- This research represents a promising quantitative approach to scale the variability of ET symptoms both for home monitoring and clinical applications.
- While past systems were based on binary classification (healthy or tremor) [3], the multi-class classification used in this method strongly differentiates between patients in different stages of ET and healthy subjects.

Methods

- The test was conducted in a Microsoft Surface Go Tablet accompanied with a stylus pen. Three ET patients implanted with an investigational DBS system and several healthy controls participated in the test through 71 trials using a customized application which logged drawn spirals for post-hoc analysis [4].
- Data is collected at 133 Hz frequency which consists of timestamps, starting and ending point of the line segments and pressure exerted by a subject on the surface tablet.
- In order to characterize each spiral in a real sequence, radius of the spatial coordinates was calculated by unravelling the spiral (transforming the cartesian coordinates to polar coordinates).
- Base features along with features based on statistics and signal processing algorithms were extracted.
- Linear discriminant analysis and gradient boosting classification were used for classifying between groups: 'healthy', 'tremor: deep brain stimulation (DBS) turned on (treated)' and 'tremor: DBS turned off (untreated)' from 37 extracted features.

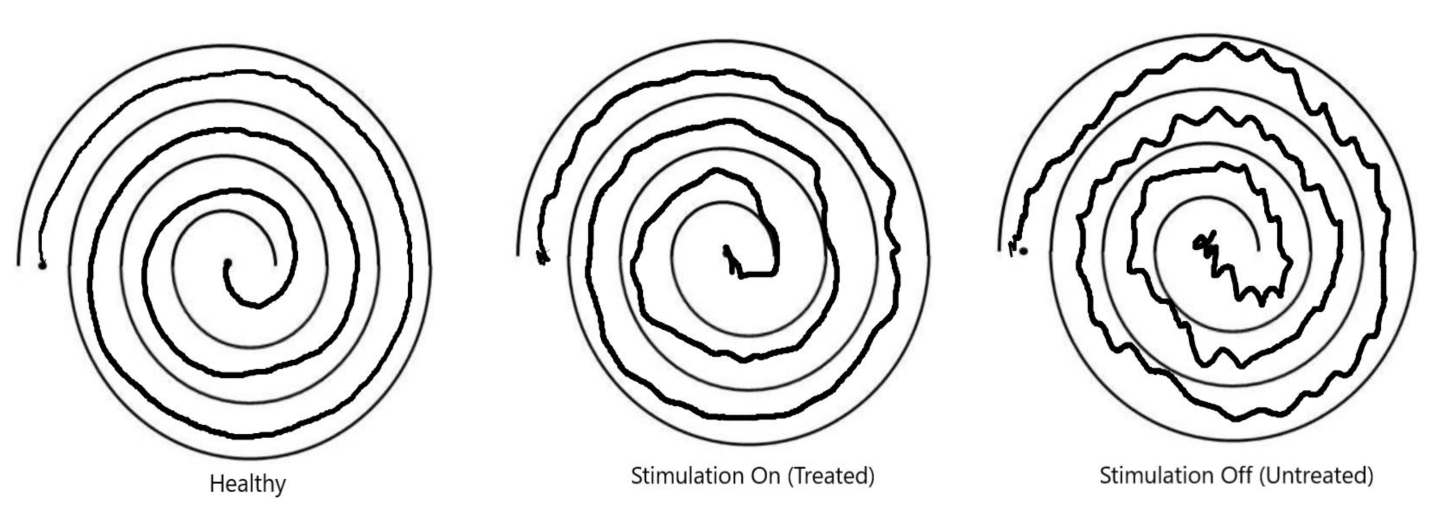

Fig. 1: Spiral drawing tasks conducted by healthy, treated and untreated classes.

Analysis

- Discrete wavelet transformation (DWT) was used to split the signals achieved from each spiral into different frequency sub-bands and features generated from each of the sub-band were used as inputs of the classifiers
- Several functions were generated to calculate the base and statistical features of sub-bands, for example, mean pressure, Bayesian confidence interval (mean, variance, standard deviation), coefficient of variation, interquartile range, n^{th} k-statistics, standard error of mean and median absolute deviation.
- Each signal was decomposed into several sub-bands returning (4*9+1)=37 features per signal where number of sub-band decomposition=4, number of statistical features= 9, number of base feature (pressure)= 1

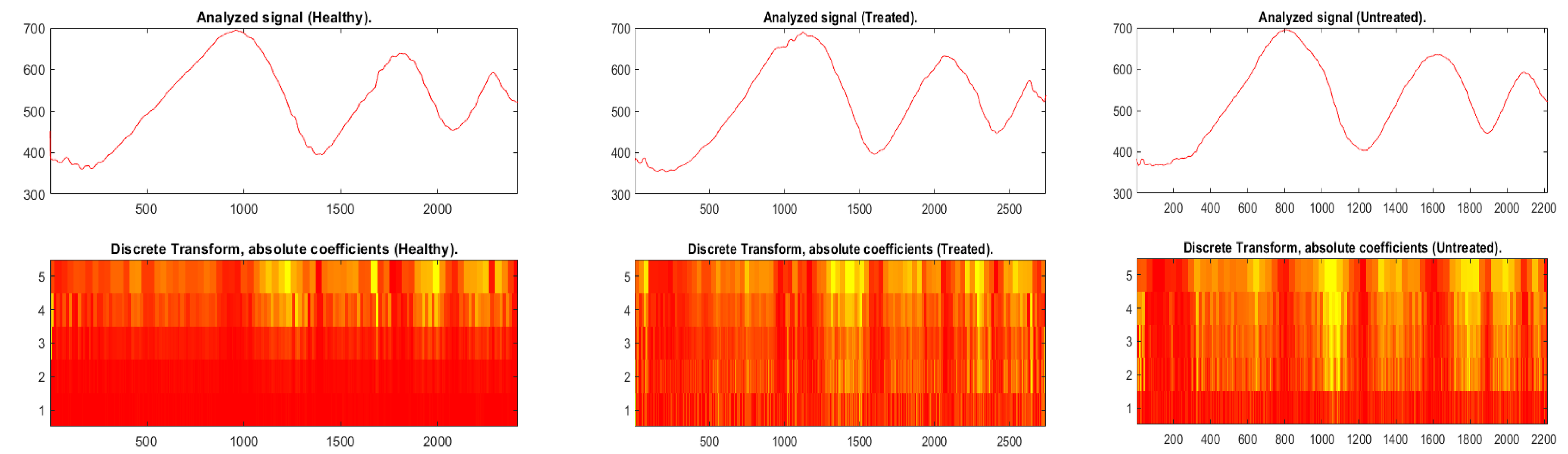

Fig. 2: Level 5 Discrete Wavelet Transformation of signals from healthy, treated and untreated classes.

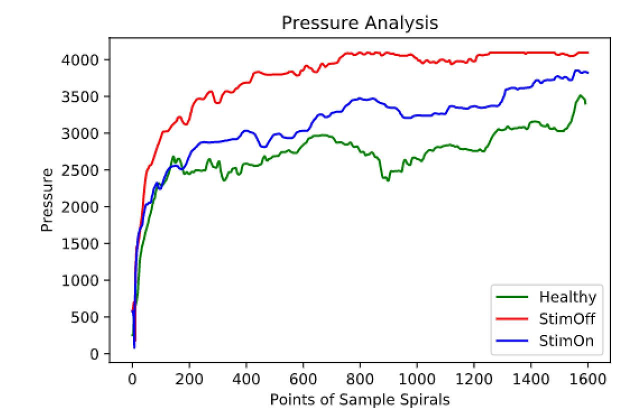

Fig. 3: Base feature analysis (pressure exerted by subjects on the surface) from healthy, treated and untreated classes

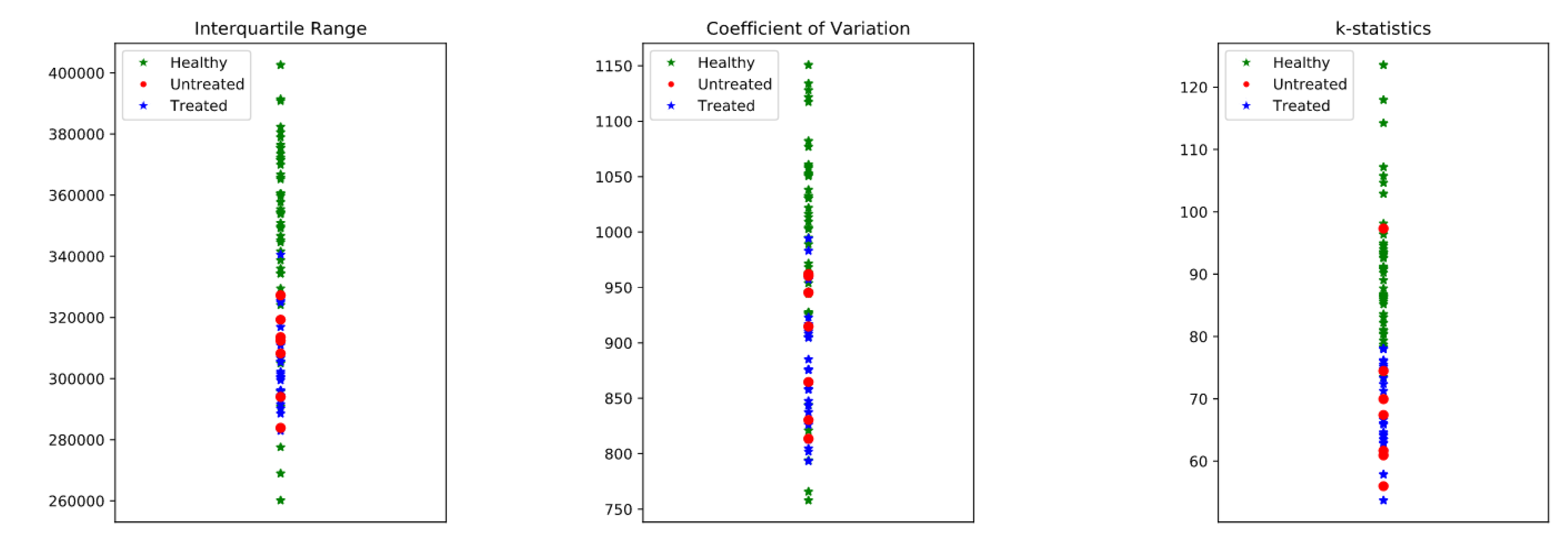

Fig. 4: Statistical feature analysis of sub-bands from discrete wavelet transformation for healthy, treated and untreated classes.

Results

- A supervised classification (gradient boosting) and an unsupervised classification (linear discriminant analysis) model were used to classify subjects which resulted in of the classification accuracy of 94.44% and 96% respectively.
- The confusion matrix shows that the gradient boosting classifier misclassified 2 treated patients as healthy subjects which proofs that sometimes tremor completely goes away while DBS is turned on. The decision boundary of linear discriminant analysis shows a promising result as well which partitions the underlying vector space into three sets.

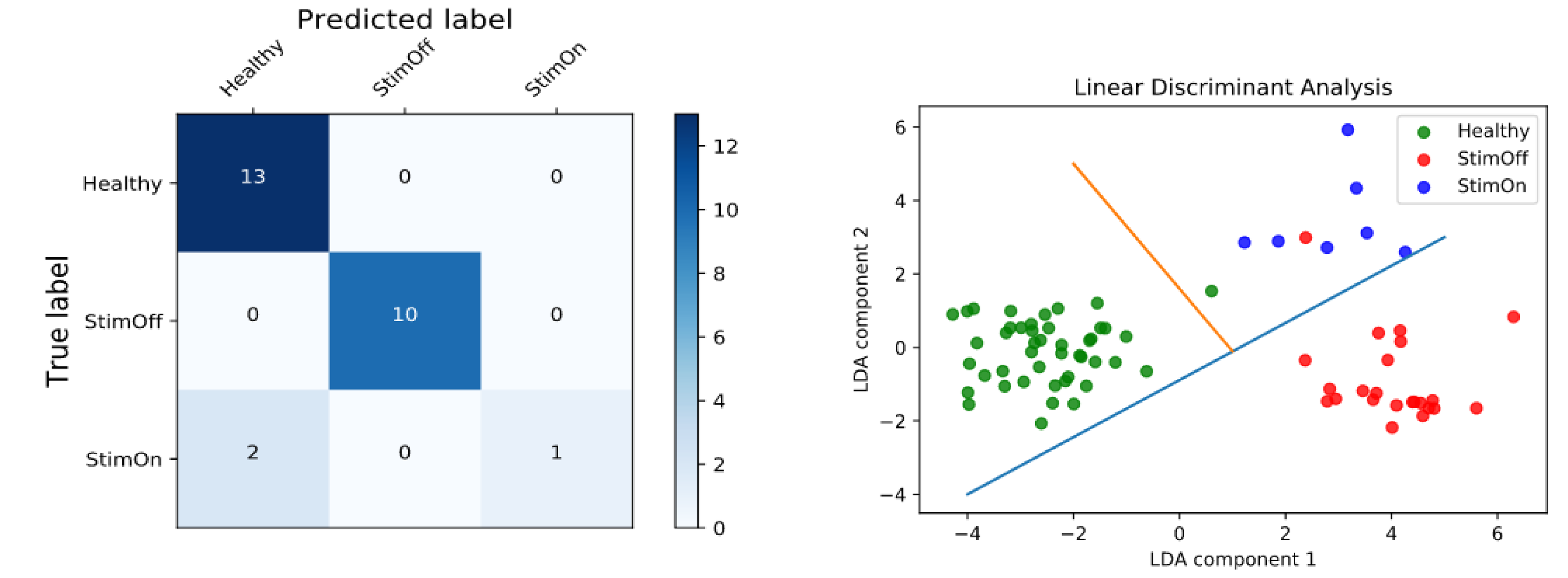

Fig. 5: Classification results, left (confusion matrix of gradient boosting classifier), right (decision boundary of linear discriminant analysis)

Discussion and Future Work

- The quantitative approach discussed in this research can be implemented to develop symptom level scores of ET in an android/iOS application.
- This score can be used to adjust stimulation parameter of a closed loop deep brain stimulation (CLDBS) system.
- The android/iOS application can pave the way of automated programming as well as a home-based monitoring system for ET disease.

References

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