Adaptive "on-off" controller for Deep Brain Stimulation (DBS)

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Introduction:
- Parkinsons Disease (PD), Essential Tremor (ET) are 2 most common progressive neurological movement disorders.
- Involves pathological tremor (4-12 Hz)
- Treatments: Drug therapy, surgical procedures (DBS).
- DBS: 1) Involves implantation of electrodes and a pacemaker, which electrically stimulates specific parts of the brain.
2) It provides remarkable therapeutic benefits for advanced stage patients.
3) FDA approved DBS operates open loop, is continuous.

For an **automatic on-off control for DBS** to be feasible:
- After cessation of a DBS-ON period, there would exist an interval of reasonable duration that is tremor-free before tremors re-appears.
- There must be a means to predict when tremor is to re-appear, in order to switch stimulation back on before the tremor re-appears.
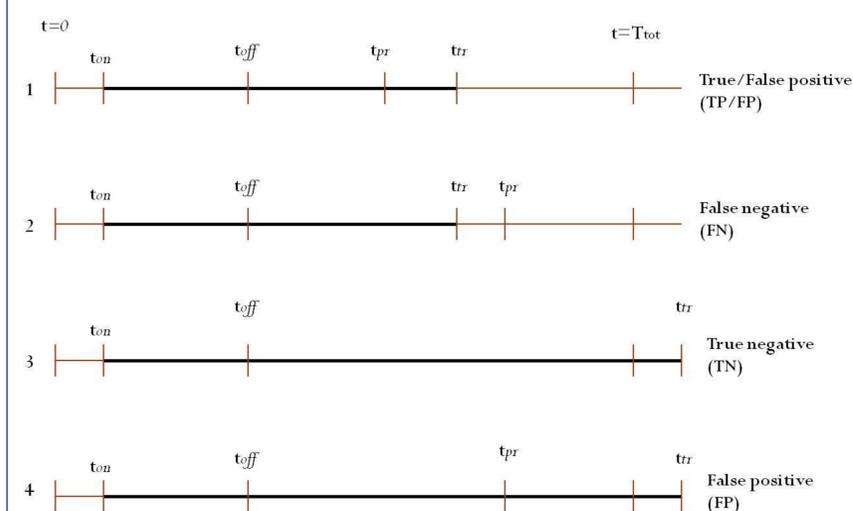- Signals used: surface EMG (sEMG), acceleration (acc)

Extensor sEMG was smoothed and following parameters were extracted:
- Spectral measures: Mean frequency, Peak frequency & signal power at peak frequency, power in (8-16 Hz) using wavelet decomposition.
- Entropy measures: wavelet entropy, sample entropy
- Recurrence measures: recurrence rate

Parameters from acc data:
Mean frequency, Peak frequency & signal power at peak frequency.

Experiment setup, signals, prediction algorithm
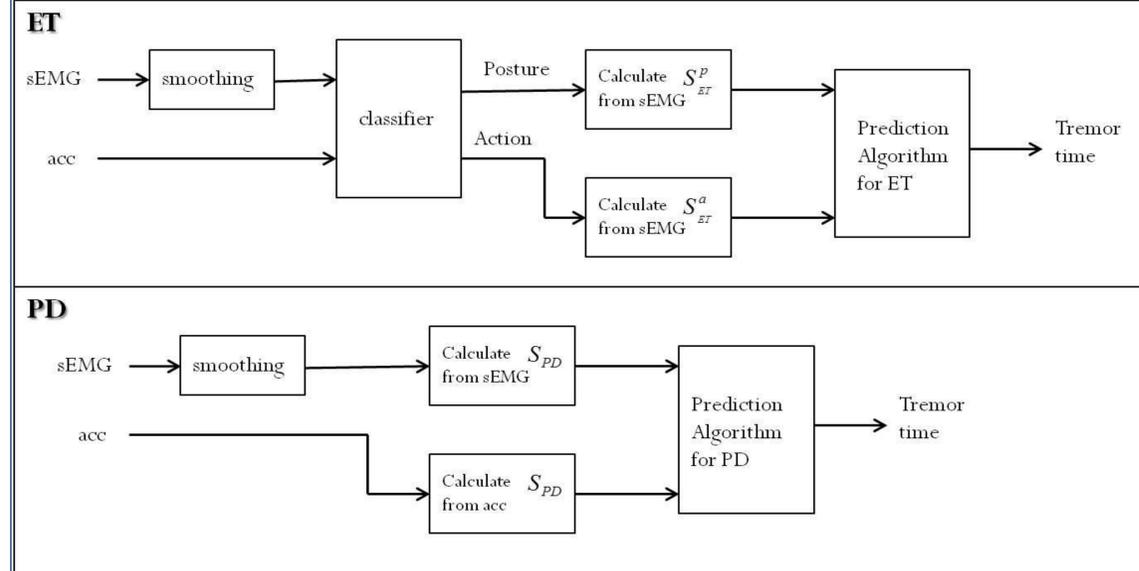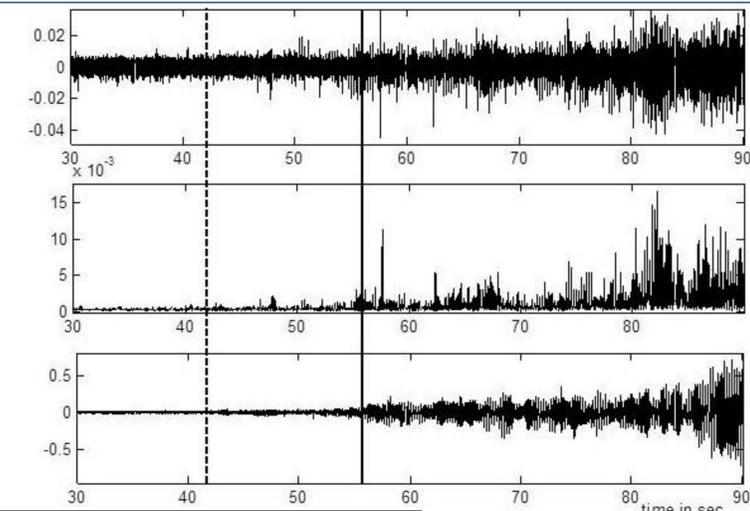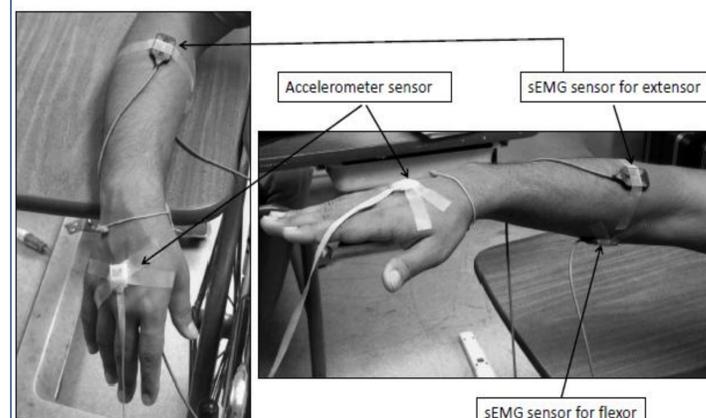
Fig:
Top (left): Setup
(right): sEMG, acc signals
Bottom:
Prediction algorithm overview

PREDICTION OUTCOME ANALYSIS:

$$A = \frac{\#TP + \#TN}{\#TP + \#TN + \#FP + \#FN}$$

$$S = \frac{\#TP}{\#TP + \#FN},$$

$$FA = \frac{\#NTD - \#TN}{\#NTD}.$$

$$R^* = \frac{t_{tr} - t_{off}}{T_{on}^*}.$$

$$\chi^2 = N \times mcc^2$$

$$mcc = \frac{(\#TP)(\#TN) - (\#FP)(\#FN)}{\sqrt{(\#TP + \#FP)(\#TP + \#FN)(\#TN + \#FP)(\#TN + \#FN)}}$$

$$R_{pd} = \sum (t_{pr} - t_{off}) / \sum (t_{tr} - t_{off}),$$

$$R_{dt} = \sum (t_{tr} - t_{off}) / \sum (t_{tr} - t_{on}),$$

$$R_{pt} = \sum (t_{pr} - t_{off}) / \sum (t_{pr} - t_{on}).$$

$$R_{pt}^* = \frac{t_{tr} - t_{off}}{t_{pr} - t_{off} + T_{on}^*}$$

Patient	A	S	FA	Rpd	Rpt, Rdt	Ton*, Rpt*	p-value
PD1	93.6	100	NC	77.6	28.6,34.1	30-35,34.1	0.006
PD2	73.1	100	NC	67.0	28.5,37.7	20-40,31	0.02
PD3	88.2	100	NC	68.8	11.5,15.9	NA	NA
PD4	75	100	27.3	80.7	34.3,39.3	20-40,42.4	0.003
All PD	80.2	100	29.4	NC	NC	NC	9.10^(-9)
ET1	80	100	NC	80.2	35.2,40.4	20-40,37.4	0.03
ET2	90	100	0	89.8	36.8,39.3	20-40,39.1	0
ET3	87.5	100	16.7	79.1	32.8,38.1	30-42,32.8	0.0005
ET4	80	100	15	88.7	48.3,51.3	15-30,45.7	0.0005
All ET	85.7	100	11.6	NC	NC	NC	0

Conclusion:
ON-OFF DBS can be designed as an add-on system to the existing one by using sEMG and acc from the tremor affected limbs of patients. The application would however be patient specific.