Real World Parkinson’s Disease Tremor and Score Prediction using Wearable IMU Sensors

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PRESENTATION OUTLINE

INTRODUCTION

FEATURE EXTRACTION

TREMOR CLASSIFIER ANALYSIS

TREMOR REGRESSION ANALYSIS

CONCLUSION
# BACKGROUND

## Pervasive Healthcare Monitoring

Significant laboratory experiments detecting tremors using IMUs for Parkinson’s Disease (PD). Less research for long term monitoring and tremor severity (lack of annotations).

## Experiments

Previous project (PD SENSORS) 6 PD patients with 6 control participants. ADL instrumented house for 4 days. Two devices, 30 samples per second, 22M samples per participant.

## Contributions

First work to continually predict PD upper limb tremor scores using machine learning in a real-world home environment.
ACCELEROMETER FOURIER ANALYSIS

Frequency-Time, $magnitude = \sqrt{x^2 + y^2 + z^2}$
**Frequency-Time Feature Extraction**

Feature Extraction

FFT-128, 50% overlap, 30x30 bins, 2.2938 sec/bin, 0.2266 Hz/bin. Model input is frequency-time vector of 30 values.
**TREMOR CLASSIFIER**

**Bandwidth Threshold** $t$

$(\text{band}1 < t)$ and $(\text{band}2 > t)$ and $(\text{band}3 < t)$

$$y_{\text{[tremor, not tremor]}} = f_\theta()$$
**TREMOR CLASSIFIER RESULTS**

Control vs PD Participants, No annotations

Expect PD higher, detection rate approaches 0 as $t$ increases.

![Detection Rate Comparison](image.png)
TREMOR CLASSIFIER RESULTS

Know Control no positives (TP=0, FN=0)

Compute False Positive Rate $FPR_C = \frac{\#\text{positives}_C}{\#\text{instances}_C} = \frac{FPC}{FPC+TN_C}$

Table: Control Participant FPR, Bandwidth 4-5 Hz, Threshold=0.020

<table>
<thead>
<tr>
<th>Participant</th>
<th>FP</th>
<th>FP+TN</th>
<th>FPR</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1</td>
<td>4</td>
<td>36847</td>
<td>0.000109</td>
</tr>
<tr>
<td>C2</td>
<td>30</td>
<td>33471</td>
<td>0.000896</td>
</tr>
<tr>
<td>C3</td>
<td>12</td>
<td>36907</td>
<td>0.000325</td>
</tr>
<tr>
<td>C4</td>
<td>14</td>
<td>49808</td>
<td>0.000281</td>
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<tr>
<td>C5</td>
<td>5</td>
<td>37287</td>
<td>0.000134</td>
</tr>
<tr>
<td>C6</td>
<td>9</td>
<td>34058</td>
<td>0.000264</td>
</tr>
</tbody>
</table>
**Tremor Severity (Self) Annotations**

**Annotation Examples**

Self assessment every 30 minutes, PD taken off medication.

- Figure: Tremor Score
- Self-Annotations: P4

- Figure: Tremor Score
- Self-Annotations: P1

\[ y_{[0.0, 3.0]} = f_\theta(\cdot) \]
TREMOR SEVERITY REGRESSION MODELS

Predict Tremor Severity (input 30 features)

Compared against Polynomial Regressors (Degree 2 and 3).

Table: Shallow Neural Network Architecture

<table>
<thead>
<tr>
<th>Layer (type)</th>
<th>Output Shape</th>
<th># Params</th>
</tr>
</thead>
<tbody>
<tr>
<td>dense (Dense, relu)</td>
<td>(None, 64)</td>
<td>1984</td>
</tr>
<tr>
<td>dense_1 (Dense, relu)</td>
<td>(None, 128)</td>
<td>8320</td>
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<tr>
<td>dense_2 (Dense, relu)</td>
<td>(None, 256)</td>
<td>33024</td>
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<tr>
<td>dense_3 (Dense, linear)</td>
<td>(None, 1)</td>
<td>257</td>
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<tr>
<td>Total params:</td>
<td></td>
<td>43,585</td>
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<tr>
<td>Trainable params:</td>
<td></td>
<td>43,585</td>
</tr>
<tr>
<td>Non-trainable params:</td>
<td></td>
<td>0</td>
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</tbody>
</table>
TREMOR SEVERITY RESULTS

Mean Absolute Error (MAE) Comparison

Neural Network superior for 5 of 6 patients versus Poly.

Figure: Tremor Score Model Results by Patient
Example Tremor Severity Predictions
CONCLUSION

Future Work

- Multi-modal HAR with camera data
- Compare time-series approaches (RNNs/LSTMs/etc.)

Contributions

- Tremor detection using traditional threshold classifier
- Tremor severity using machine learning regressors

Take Away - Suitable for disease progression

Real world (uncontrolled, long term, minimal annotations) tremor detection and severity inference approaches.
QUESTIONS