FREQUENCY ANALYSIS AND TRANSFER LEARNING ACROSS DIFFERENT BODY SENSOR LOCATIONS IN PARKINSON'S DISEASE DETECTION USING INERTIAL SIGNALS

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Introduction

- **Tremor analysis** using **Deep Learning** in different parts of the body for **detection of Parkinson's** disease and its severity
- **Early detection** and medical treatment on the first stages of the disease could **improve quality of life** of the patients
- Use of non-intrusive **wearables** for data collection

Previous works

- Hypothesis stating that data received by the thigh sensors are similar to those of the forearms
- 92.4 % accuracy rate using 6.4-second windows of raw data but training and testing with signals from the same subject, not LOSO
- 60.33 ± 1,00 % accuracy rate using LOSO with 3.2-second windows

Introduction

Objectives

Analyse what information is useful for the model performing certain experiments

1. Frequency analysis to obtain the **frequency range** with more **useful information** for PD detection

2. **Transfer learning** across the **sensor locations** on different body parts, discussing accuracy rates acquired training with one sensor and testing with another

Materials and Methods

PD-BIOSTAMPRC21 dataset – 31 subjects

Sampling rate of **31,25 Hz**

Inertial signals

Inertial signals lumped into Pickle files

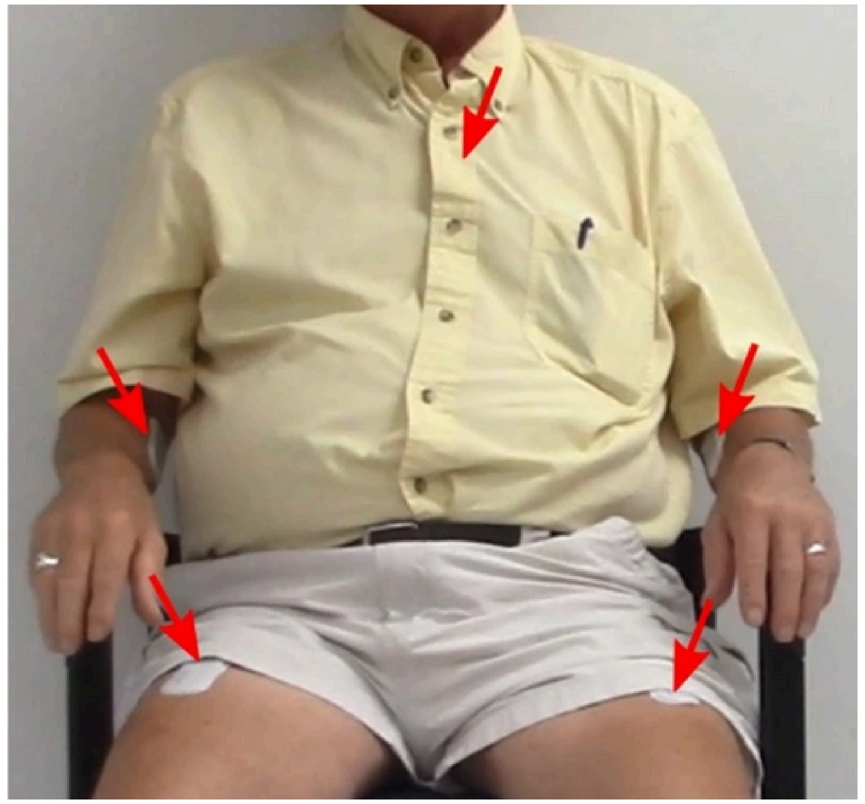
[X ch, Y ch, Z ch, X lh, Y lh, Z lh, X ll, Y ll, Z ll, X rh, Y rh, Z rh, X rl, Y rl, Z rl]

Chest	Left forearm	Left thigh	Right forearm	Right thigh

Labelling

- '1' : Control
- '2' : Parkinson

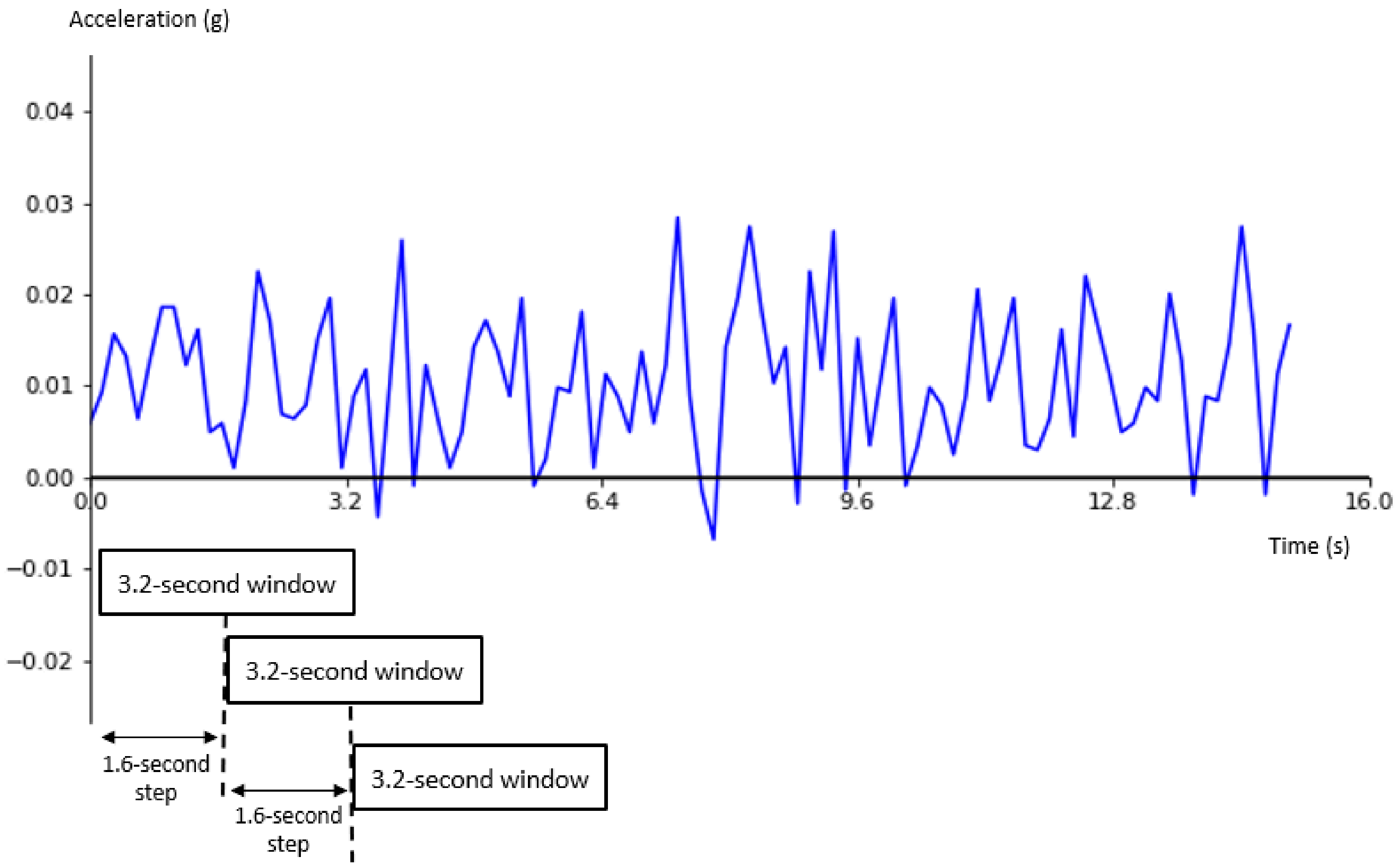
Sensors location



Materials and Methods

Signal processing

Sliding window segmentation



Raw

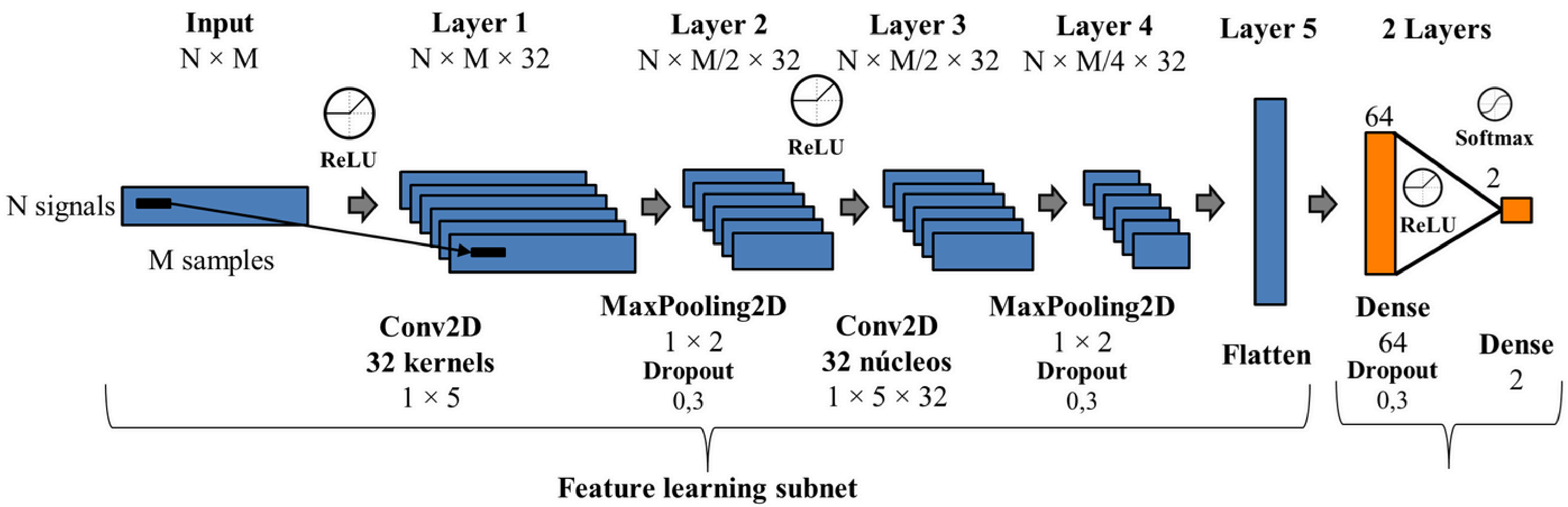
- 100 time samples (obtained with the sampling rate and 3.2-seconds window)

FFT (Fast Fourier Transform)

- 50 time samples (obtained with half of the sampling rate)
- The number of time samples is equivalent to frequency divisions

Materials and Methods

Deep Learning Architecture (CNN)



Layer	Output form	Param #	Activation function	Characteristics
Input	(None, 15, 50, 1)	-	-	-
Conv 2D	(None, 15, 50, 32)	192	ReLU	Kernels = 32 Size = 1x5
Max Pooling 2D	(None, 15, 25, 32)	0	-	Size = 1x2
Dropout	(None, 15, 25, 32)	0	-	Dropout = 0,3
Conv 2D	(None, 15, 25, 32)	5152	ReLU	Kernels = 32 Size = 1x5
Max Pooling 2D	(None, 15, 12, 32)	0	-	Size = 1x2
Dropout	(None, 15, 12, 32)	0	-	Dropout = 0,3
Flatten	(None, 5760)	0	-	-
Dense	(None, 64)	368704	ReLU	Neurons = 64
Dropout	(None, 64)	0	-	Dropout = 0,3
Dense	(None, 2)	130	Softmax	Neurons = 2
Output	(None, 2)	-	-	-

Input layer

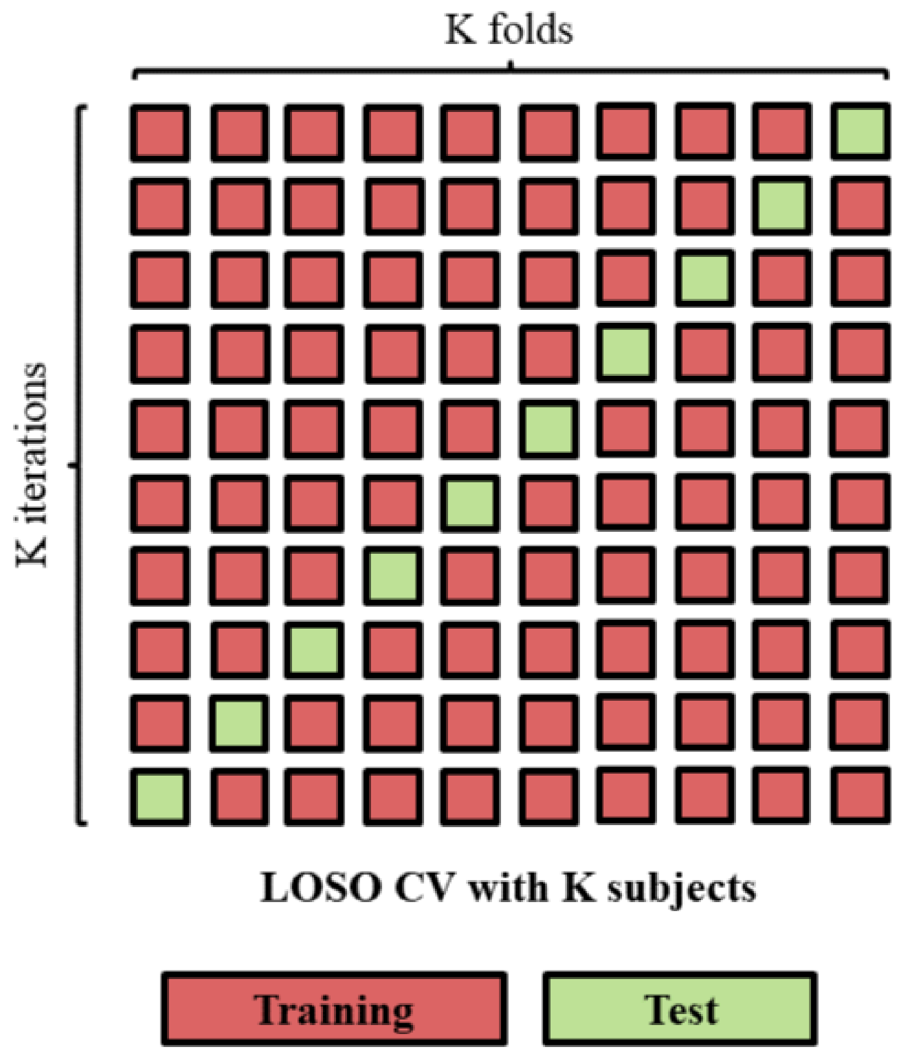
(Signals, Samples, Kernel or neurons)

(Number of signals or sensors, Number of windows, Kernel or neurons)

Materials and Methods

Evaluation Methodology

LOSO



Evaluation metric

$$\text{Accuracy rate} = \frac{1}{N}\sum_{i=1}^{C} P_{ii}$$

with their confidence intervals (CI)

$$\text{CI (95\%)} = \pm 1{,}96 \cdot \sqrt{\frac{\textit{Metric rate} \cdot (100 - \textit{Metric rate})}{N}}$$

Results and Discussion

Frequency Analysis

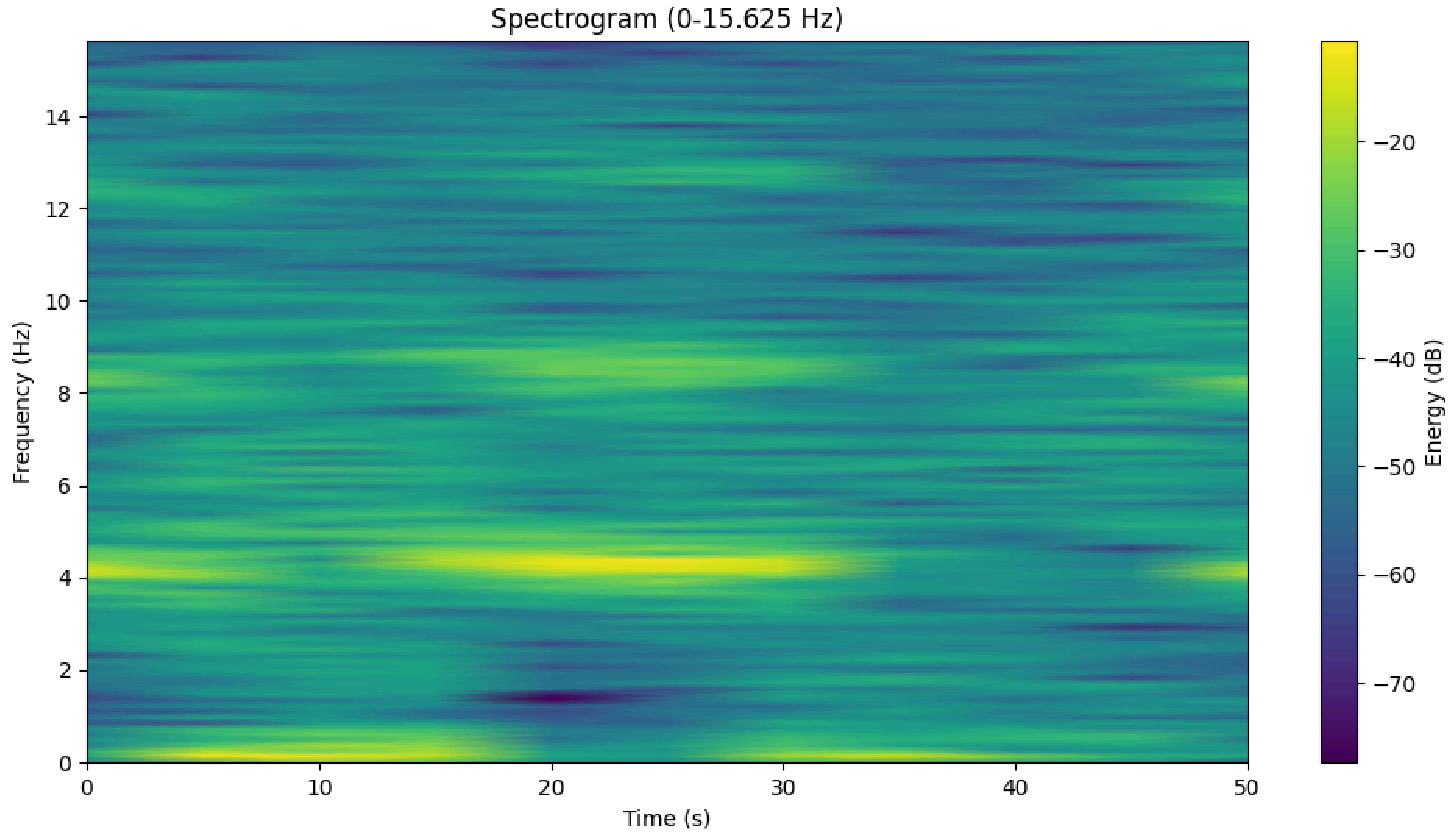
Sensor	Frequency range (Hz)	Accuracy rate (%)
All	0-15	77.46 ± 0.60
	0-5	75.75 ± 0.62
	5-10	61.87 ± 0.70
	10-15	56.85 ± 0.71
ch - Chest	0-15	73.28 ± 0.64
	0-5	70.34 ± 0.66
	5-10	53.39 ± 0.72
	10-15	46.80 ± 0.72
lh - Left forearm	0-15	65.71 ± 0.68
	0-5	65.95 ± 0.68
	5-10	46.38 ± 0.72
	10-15	44.71 ± 0.72
ll - Left thigh	0-15	62.90 ± 0.69
	0-5	62.15 ± 0.70
	5-10	50.94 ± 0.72
	10-15	48.45 ± 0.72
rh - Right forearm	0-15	64.95 ± 0.69
	0-5	63.68 ± 0.69
	5-10	51.49 ± 0.72
	10-15	48.52 ± 0.72
rl - Right thigh	0-15	64.55 ± 0.69
	0-5	65.77 ± 0.69
	5-10	56.07 ± 0.71
	10-15	43.69 ± 0.71

Input layer for 0 to 5 Hz with all the sensors

(None, 15, 16, 1)

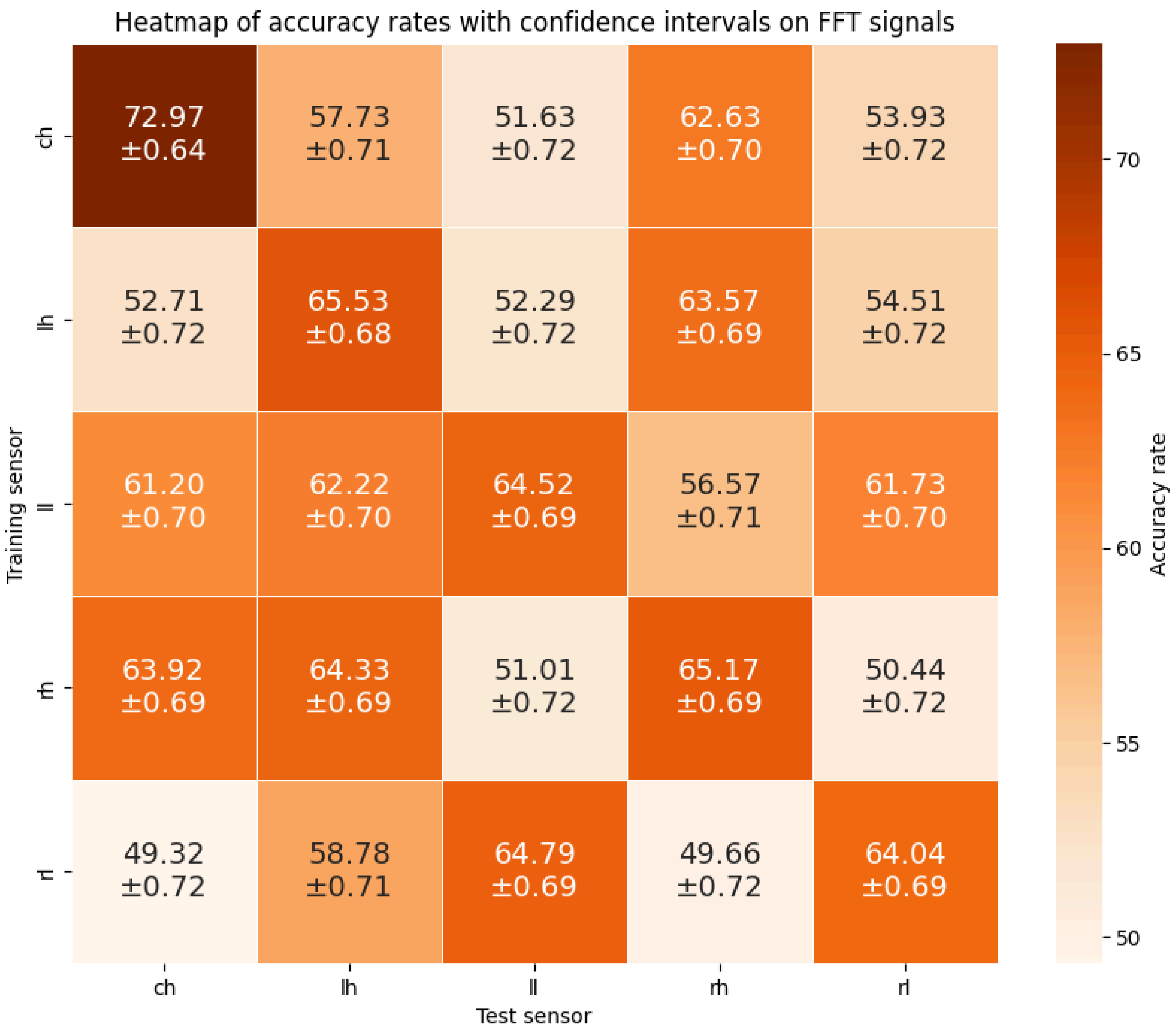
1. Similar values of accuracy rates obtained from 0 to 5 Hz to the whole frequency range

Highest energy level occurs at 4 Hz frequency



Transfer learning across different sensor locations

FFT (Fast Fourier Transform)



Input layer for 0 to 15 Hz with one sensor

(None, 3, 50, 1)

1. Best rate is obtained training and testing with the sensor on the same location (principal diagonal)
2. Unlike hypothesised in previous work, **there is no transfer of information between the thighs and forearms**
3. Evaluating on the sensors located in the same location but opposite sides of the body **offer similar tremor information**

↓

Facility for wearables placement

Conclusions

1. Similar accuracy rates using a frequency range of 0 to 5 Hz. On the left thigh sensor, of 62.15 ± 0.70 %, compared to the full frequency range available (0 to 15.625 Hz), with 62.90 ± 0.69 %

2. There is a relationship on a specific sensor and the one in the opposite body part. Training with the left forearm sensor and evaluating with the right forearm: 63.57± 0.69 %, while training and evaluating with the right forearm: 65.17 ± 0.69 %

3. Right forearm sensor also offers a high accuracy rate while evaluating the model with the chest sensor

Conclusions

Future studies

1. Work with new datasets with a higher number of subjects to certify the results

2. Developing an interactive wearable application to build real time systems to those who may need those

3. Create a regression system to estimate the Unified Parkinson's Disease Rating Scale (UPDRS) from tremor signals

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THANK YOU FOR YOUR ATTENTION

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