Module 3

Introduction to Wearables- Time Series

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THE MICHAEL J. FOX FOUNDATION FOR PARKINSON'S RESEARCH
Founding funders:
UKRI
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Announcements

- **Next workshop: 11th November, CXGH 1.14 (Glenister Lecture Theatre), Charing Cross Campus (W6 8RP.)**

Lecture theatres

CXGH 1.14 - Glenister Lecture Theatre

- Today: Introduction to time-series data + Tutorial 3.

- **If you haven't finished Tutorial 2, please do so.**

- Tomorrow: Hackathon expectations overview.

- Tuesday: All tutorial solutions released.

- Reminder: Notebook → Google → TA or MT

What We'll Do Today

- **Lecture:** Short introduction to Wearables – Times Series Data

Tutorial / Challenge — Intro to **time-series data**: clean signals and extract features from **ECG** and **accelerometer** data.

- Work with real biomedical signals (ECG + accelerometer).
- Preprocessing: handle missing data, smoothing, filtering, normalization.
- ECG: R-peak detection, RR intervals, heart rate variability.
- Accelerometer: windowing, basic movement features.
- Feature extraction in time and frequency domains.

Cecilia Rodriguez

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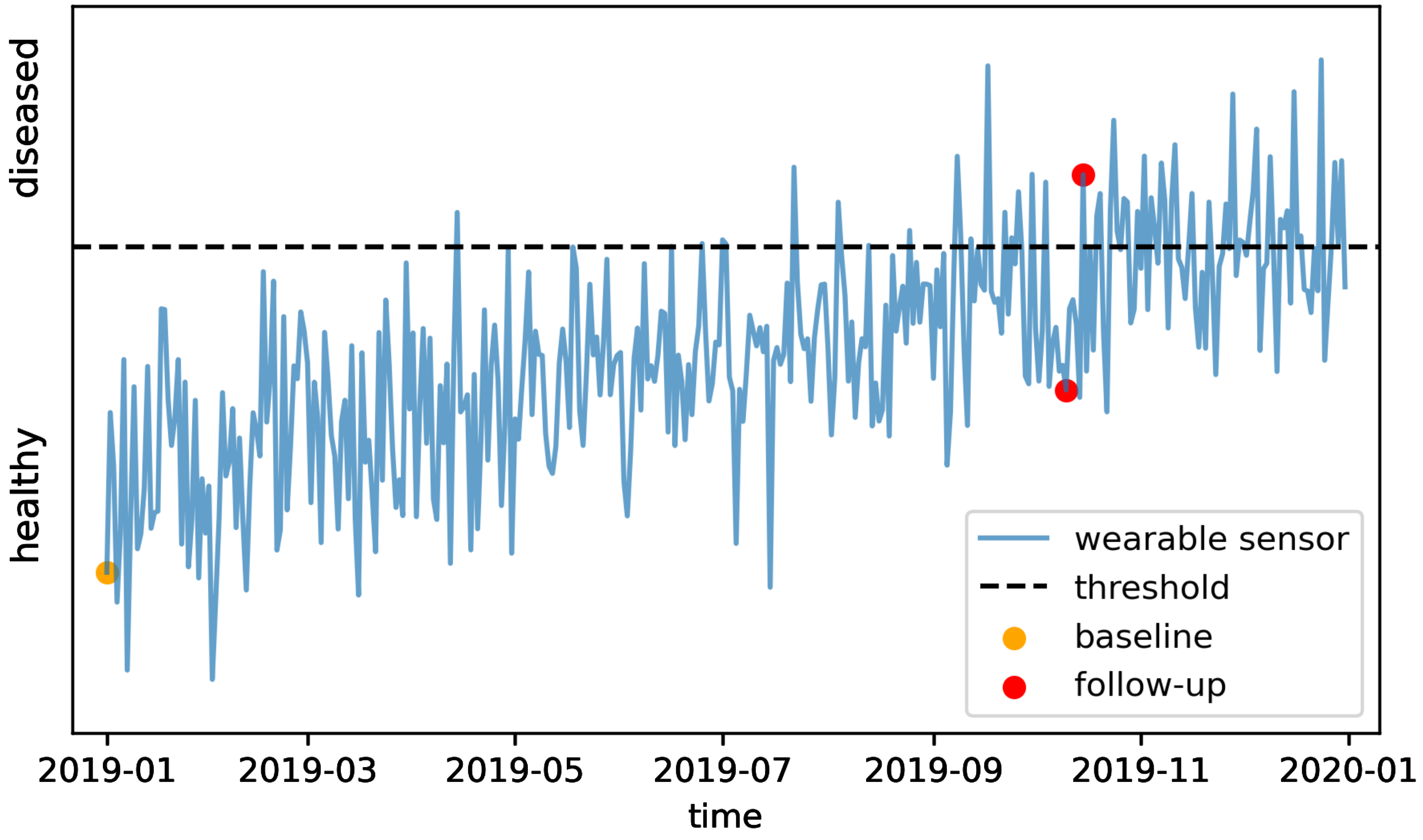
Why should we focus on digital markers?



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Monitoring: What do we currently use?

Clinical visits: UPDRS

3.1 SPEECH	SCORE
Instructions to examiner: Listen to the patient's free-flowing speech and engage in conversation if necessary. Suggested topics: ask about the patient's work, hobbies, exercise, or how he got to the doctor's office. Evaluate volume, modulation (prosody) and clarity, including slurring, palilalia (repetition of syllables), and tachyphemia (rapid speech, running syllables together).	
0: Normal: No speech problems.	
1: Slight: Loss of modulation, diction, or volume, but still all words easy to understand.	
2: Mild: Loss of modulation, diction, or volume, with a few words unclear, but the overall sentences easy to follow.	☐
3: Moderate: Speech is difficult to understand to the point that some, but not most, sentences are poorly understood.	
4: Severe: Most speech is difficult to understand or unintelligible.	

3.2 FACIAL EXPRESSION

Instructions to examiner: Observe the patient sitting at rest for 10 seconds, w while talking. Observe eye-blink frequency, masked facies or loss of facial ex smiling, and parting of lips.

0: Normal: Normal facial expression.

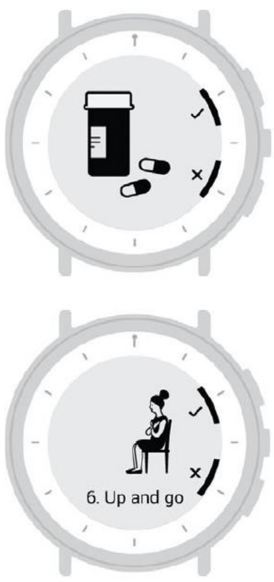
1: Slight: Minimal masked facies manifested only by decreased freq

2: Mild: In addition to decreased eye-blink frequency, masked facie face as well, namely fewer movements around the mouth, spontaneous smiling, but lips not parted.

3: Moderate: Masked facies with lips parted some of the time when the

4: Severe: Masked facies with lips parted most of the time when the r

Active virtual assessment



Passive digital motor features

Rune Labs scores FDA 510(k) to monitor Parkinson's symptoms on Apple Watch

The StrivePD app uses Apple's Movement Disorder API to track tremors and uncontrolled body movement.

By **Emily Olsen** | June 14, 2022 | 11:42 am

SHARE Share 20.6K

NeuroRPM obtains FDA 510(k) for Parkinson's monitoring on Apple Watch

The AI-powered app allows for remote monitoring of common Parkinson's disease symptoms such as bradykinesia, tremor and dyskinesia via an Apple Watch.

By **Jessica Hagen** | March 24, 2023 | 11:18 am

SHARE Share 268

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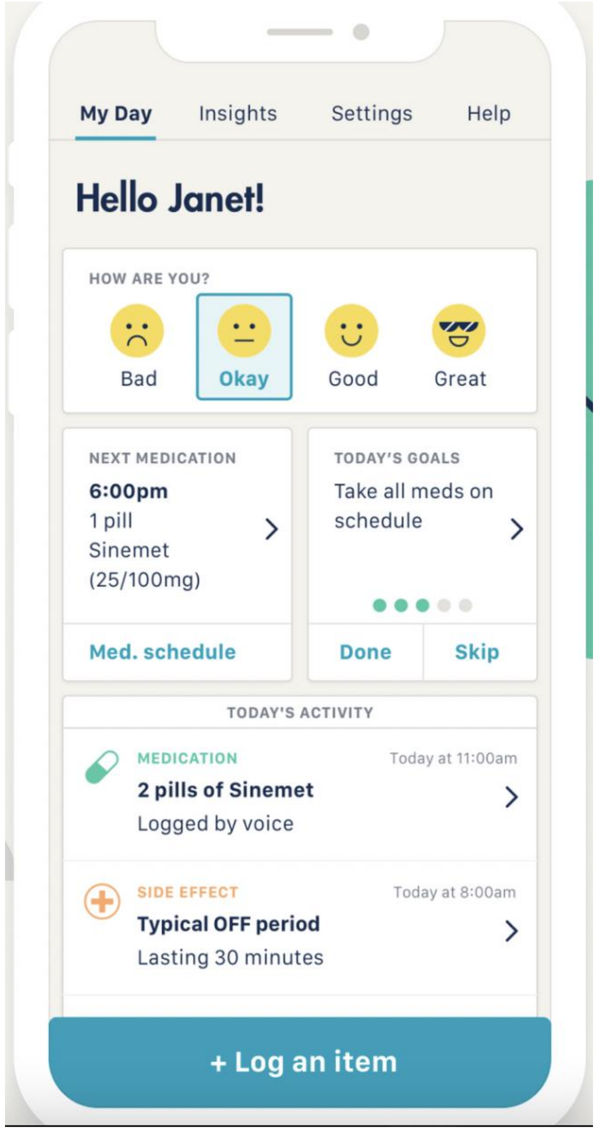
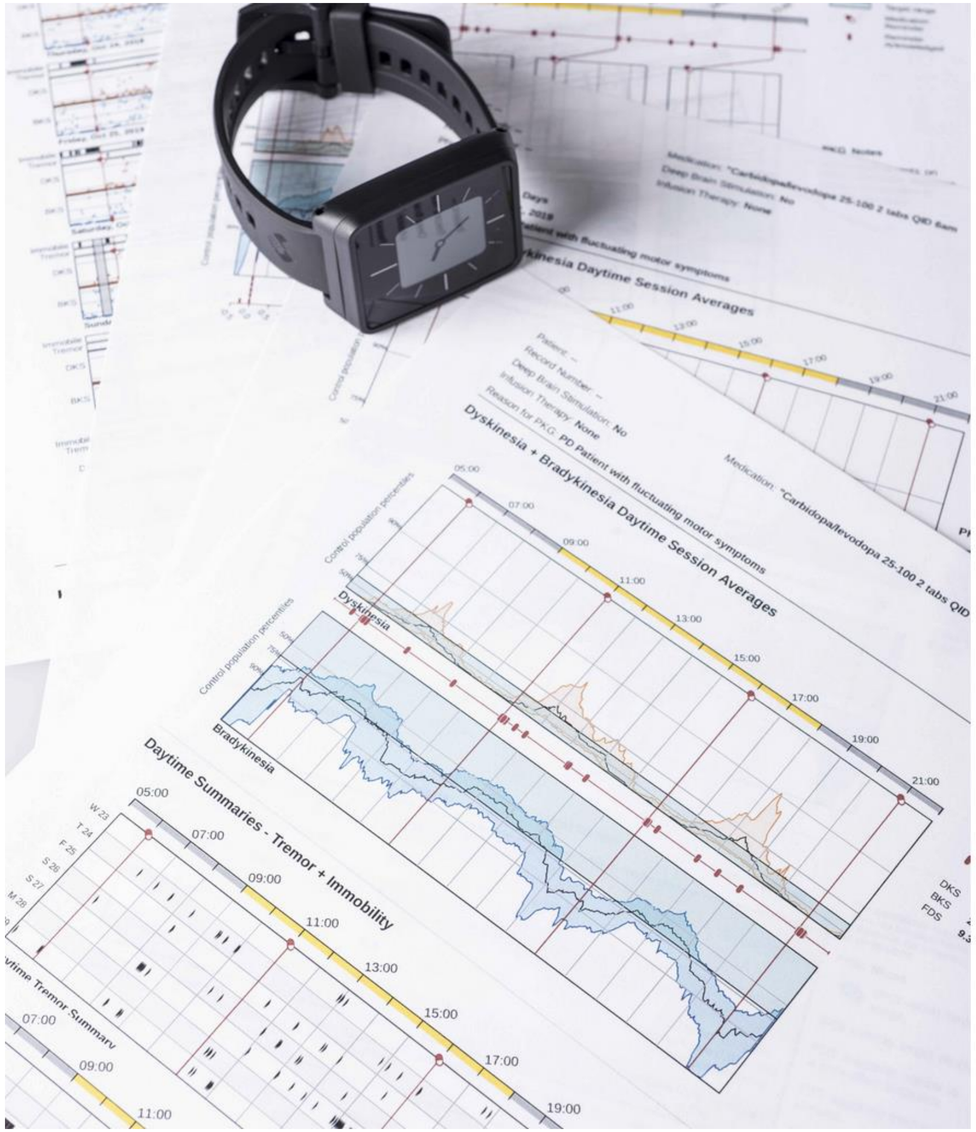
StrivePD



https://www.strive.group/

PKG



https://pkgcare.com/

Smartwatch data can predict, up to 7 years in advance, who is going to develop Parkinson's disease.

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nature medicine

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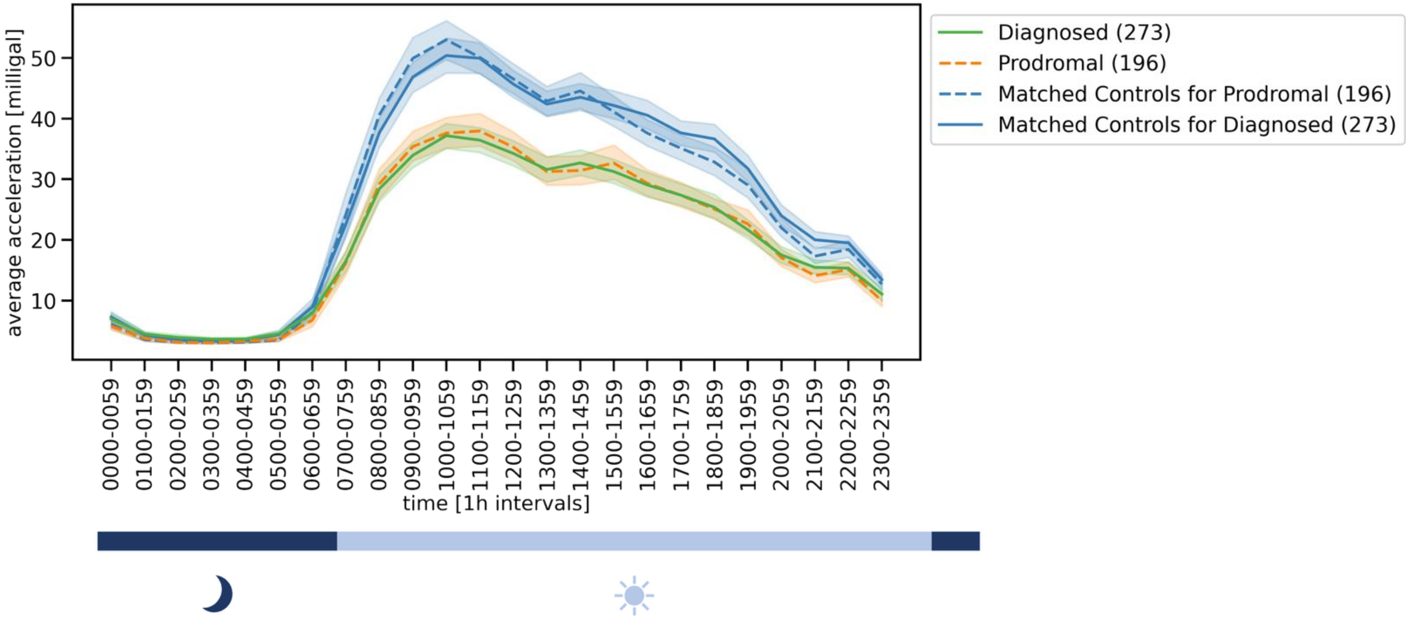
Article | Published: 03 July 2023

Wearable movement-tracking data identify Parkinson's disease years before clinical diagnosis



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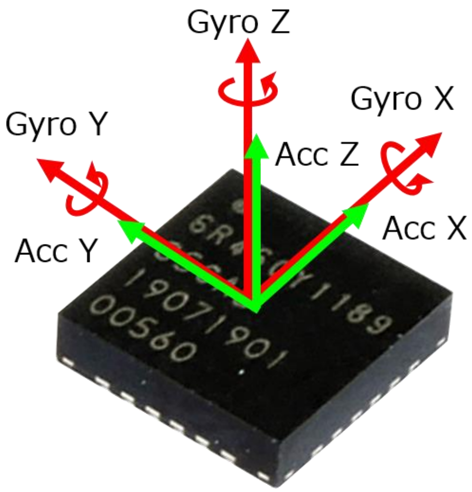
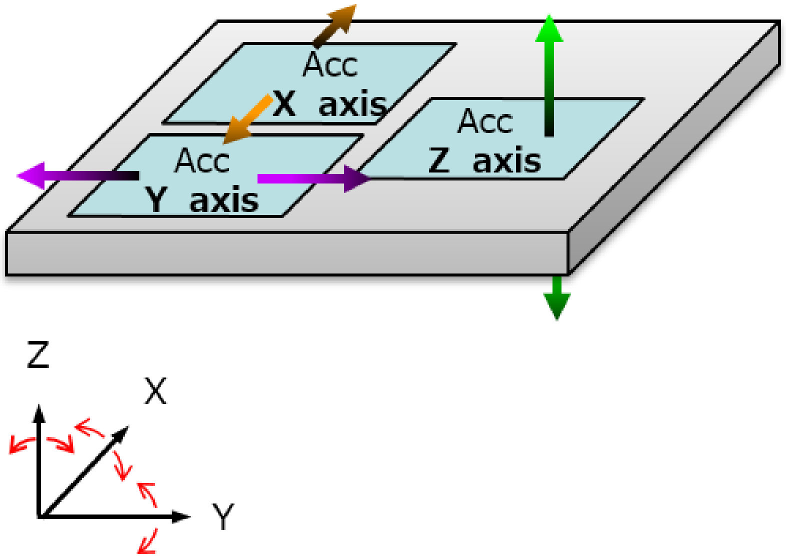
Wearables Time-Series Data

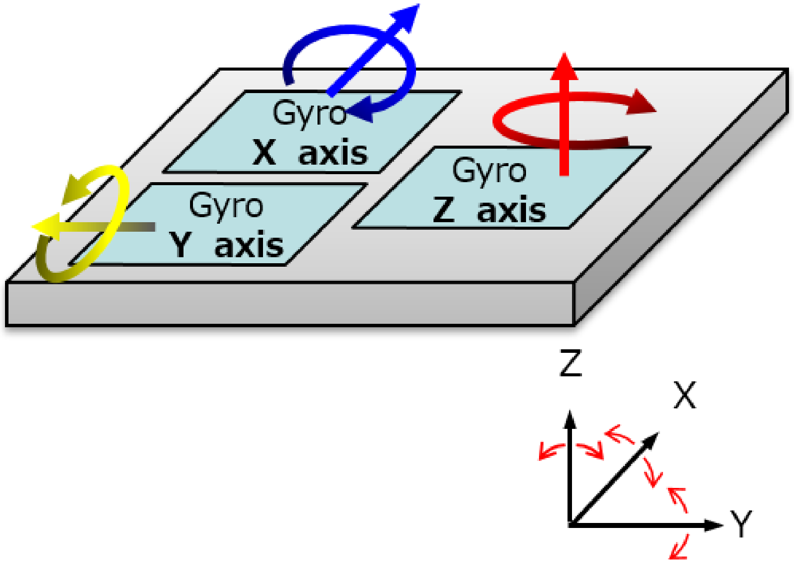
6-dimensional inertial measurement unit, or **IMU**.



3-axis accelerometer



3-axis gyroscope



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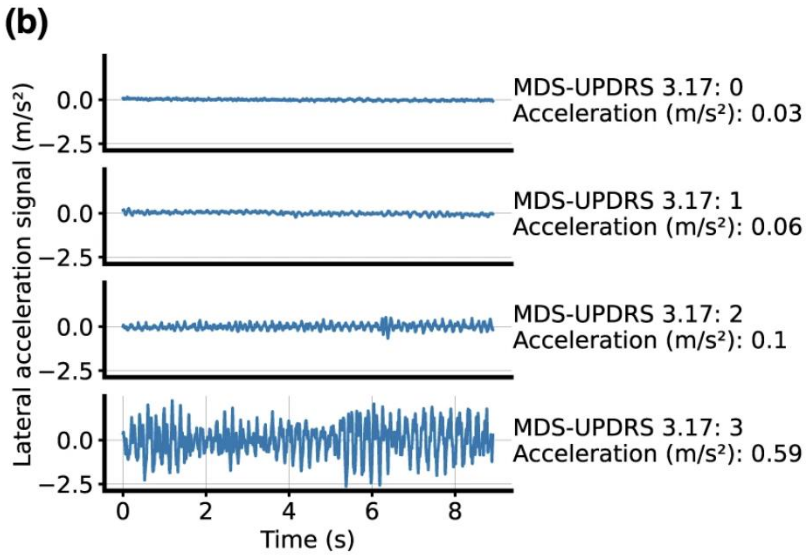
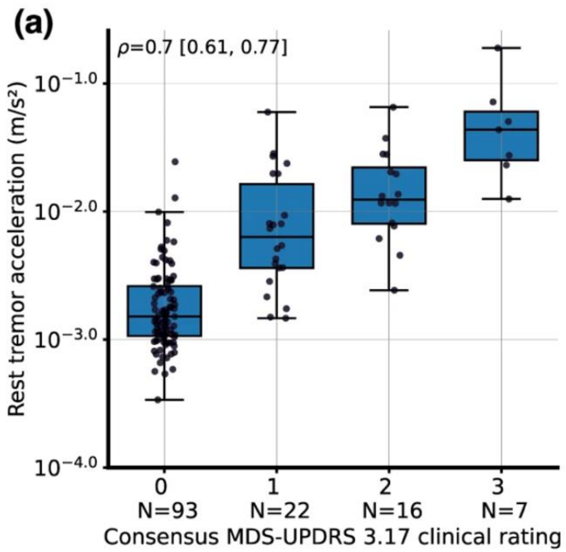
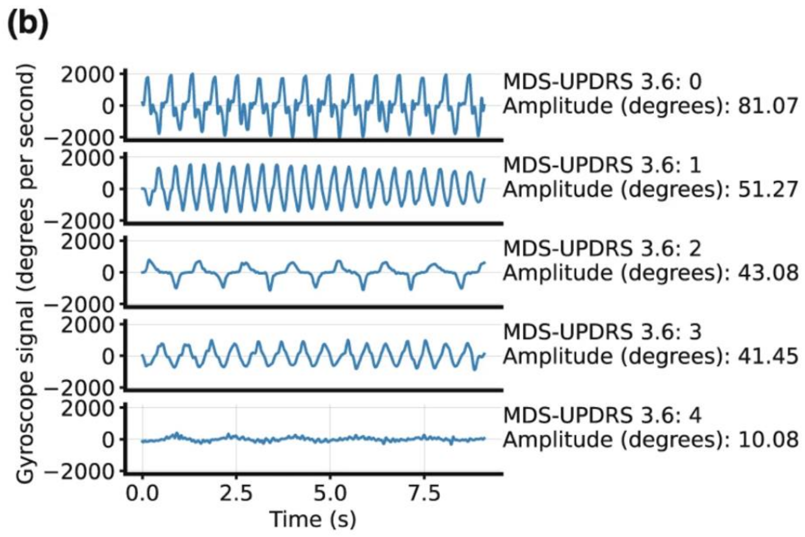
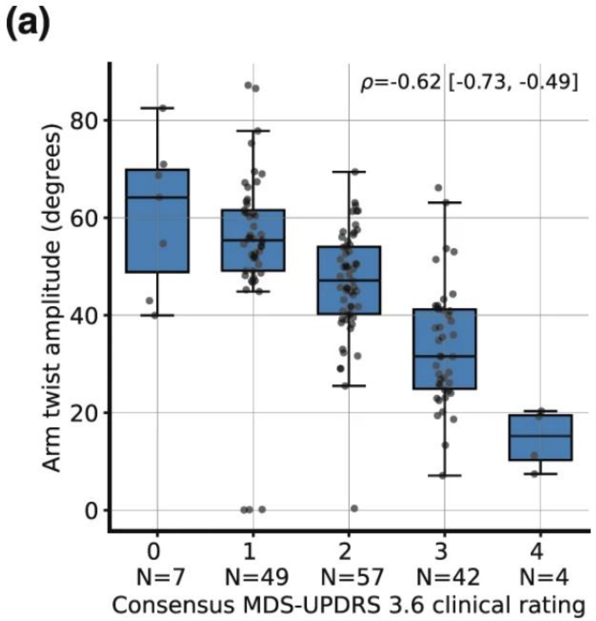
From Raw Signals to Clinical Meaning: Tremor and Bradykinesia

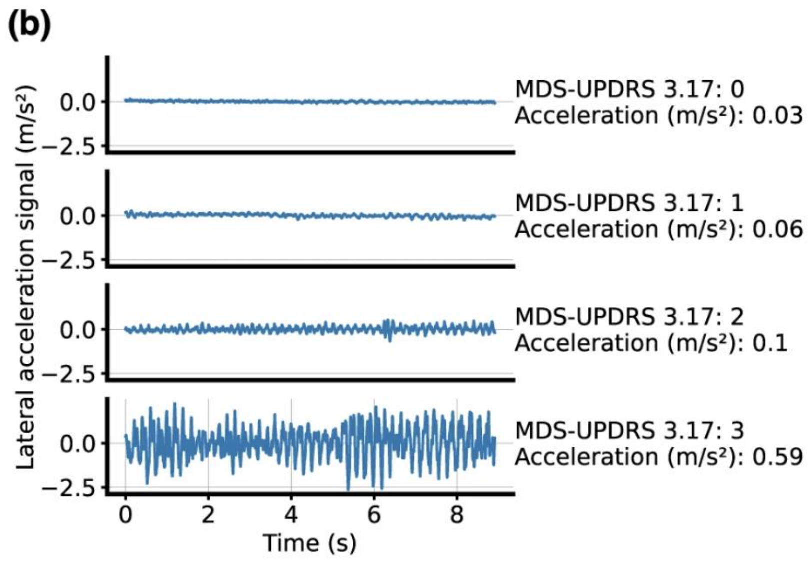


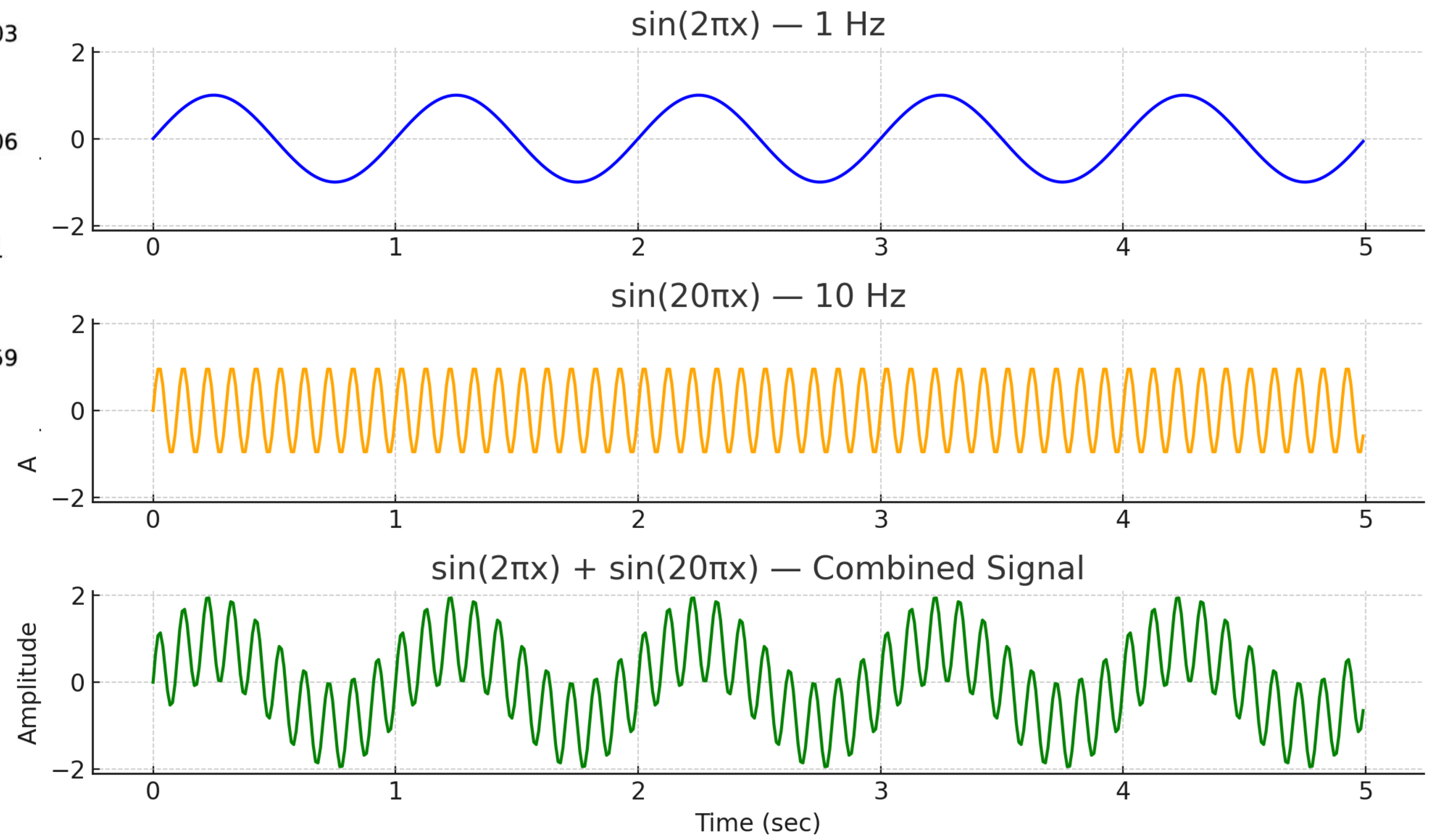






Revealing Hidden Rhythms in Wearable Sensor Data: Frequency Domain





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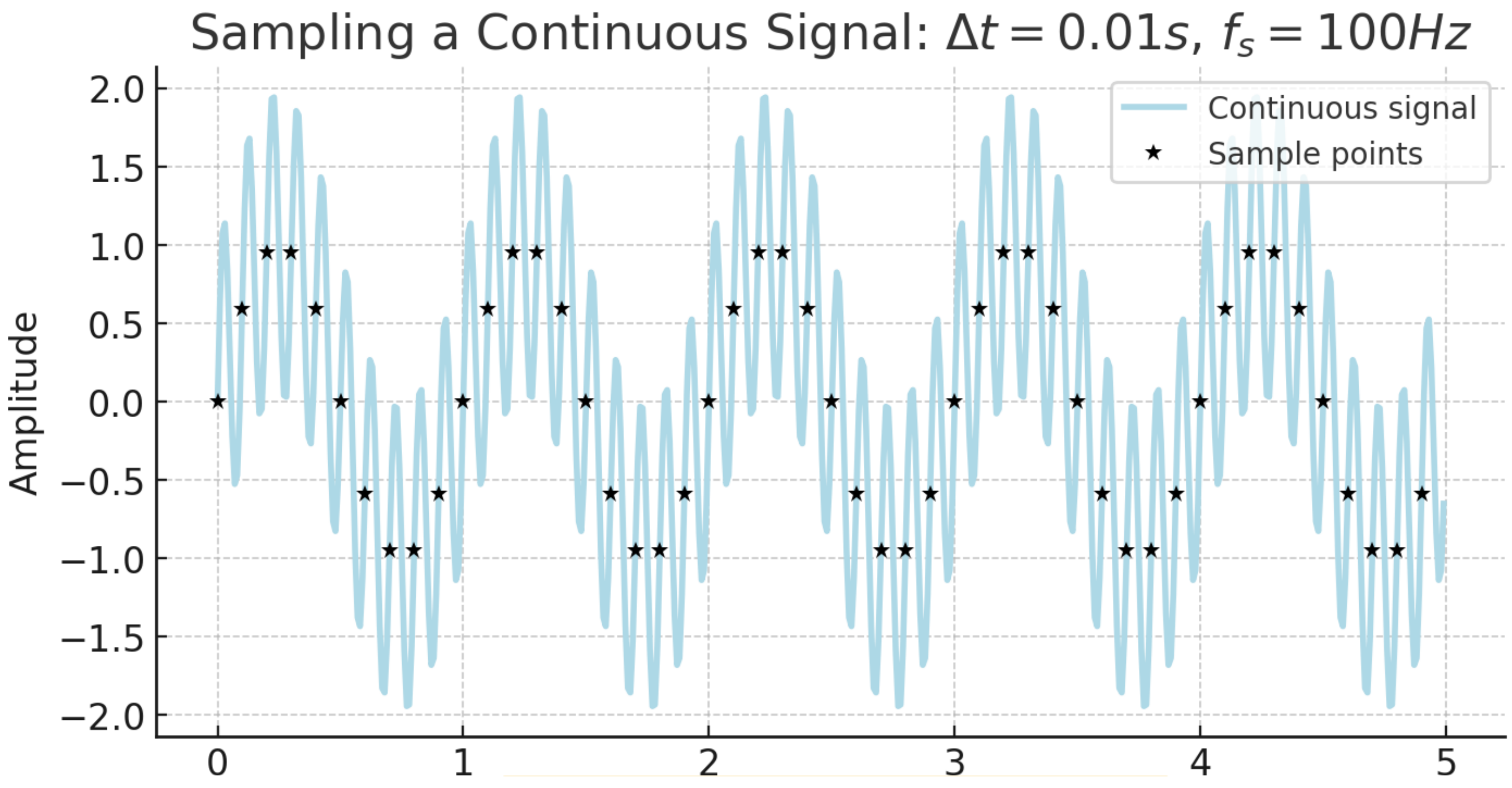
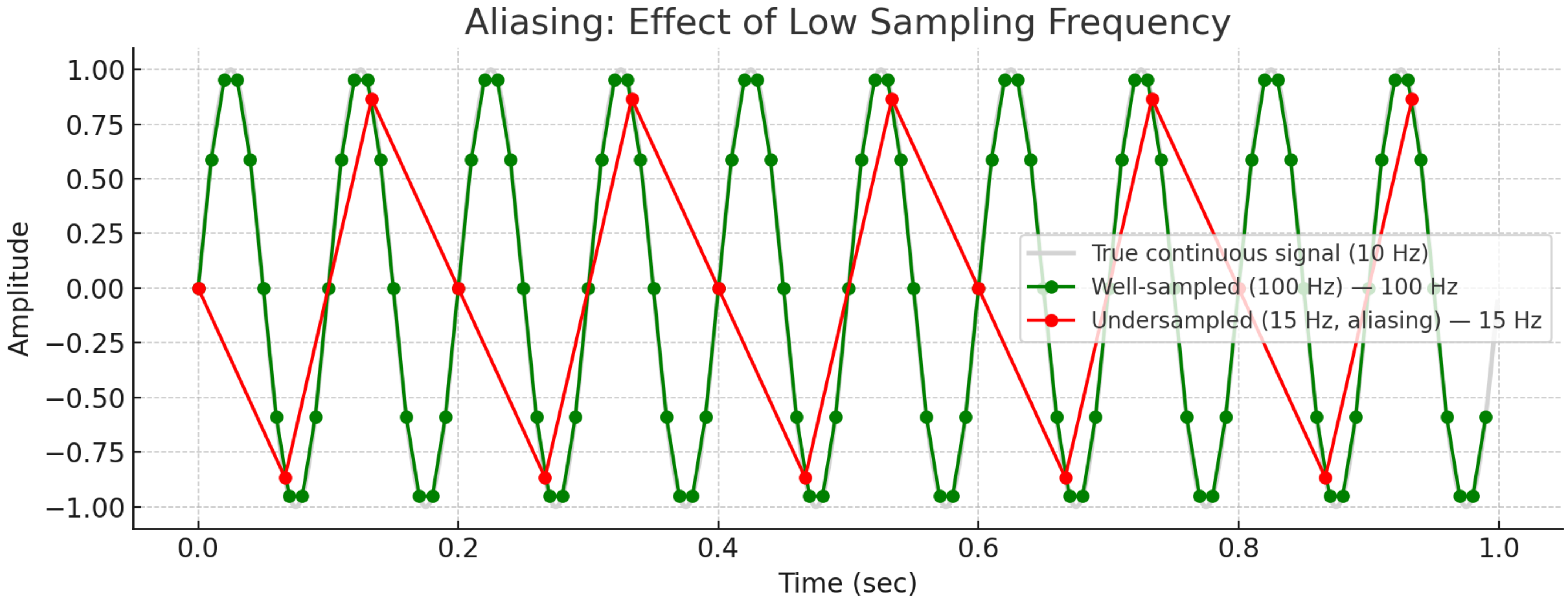
Revealing Hidden Rhythms in Wearable Sensor Data: Sampling Rate



$$\Delta t = 0.01sec = 10ms \Rightarrow f_s = \frac{1}{\Delta t} = 100Hz \mid Hz = \frac{1}{sec}$$

Aliasing — when a signal is sampled below its true frequency



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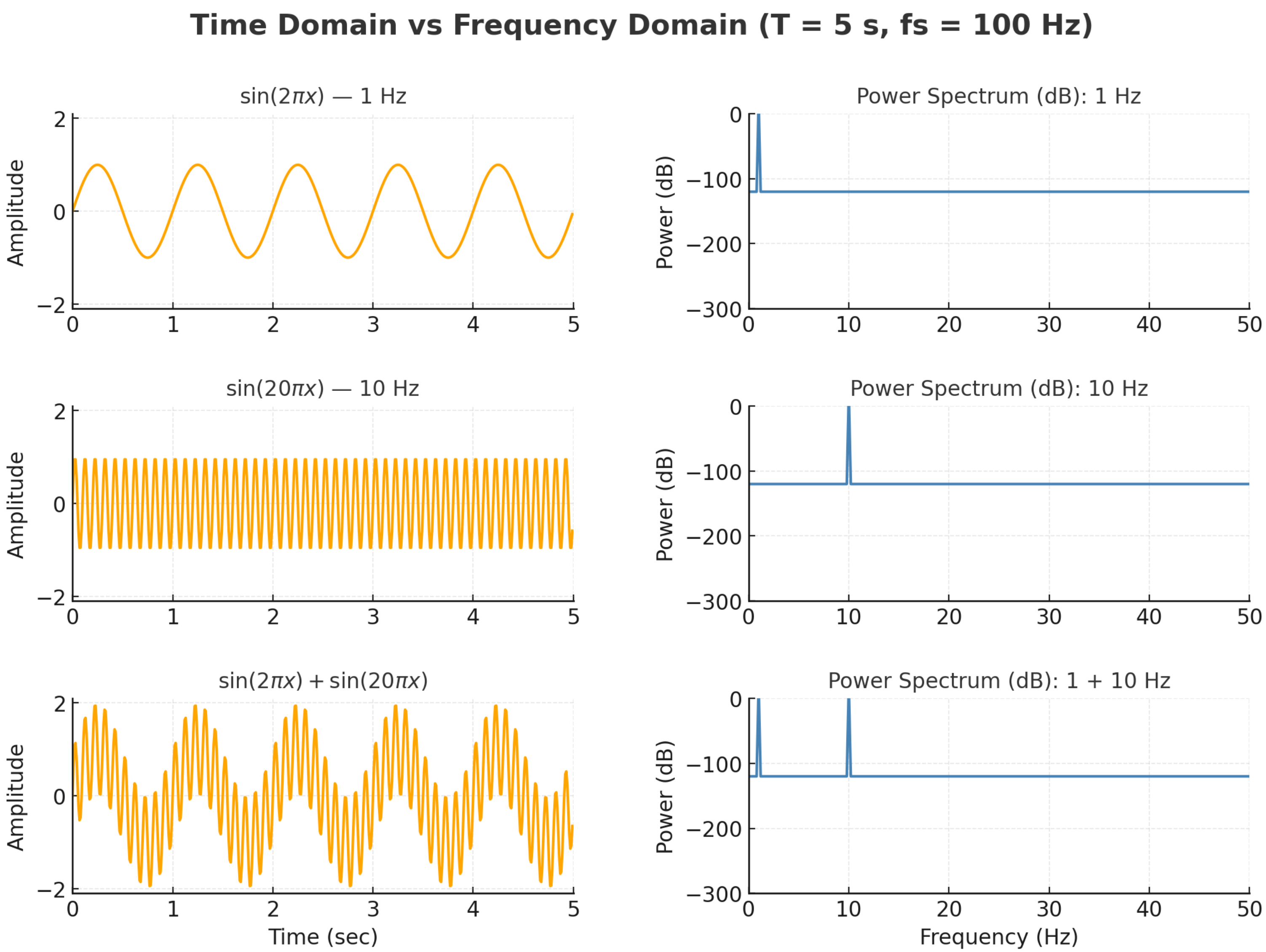
Power Spectral Density (PSD)
how the power of a signal is distributed across different frequencies



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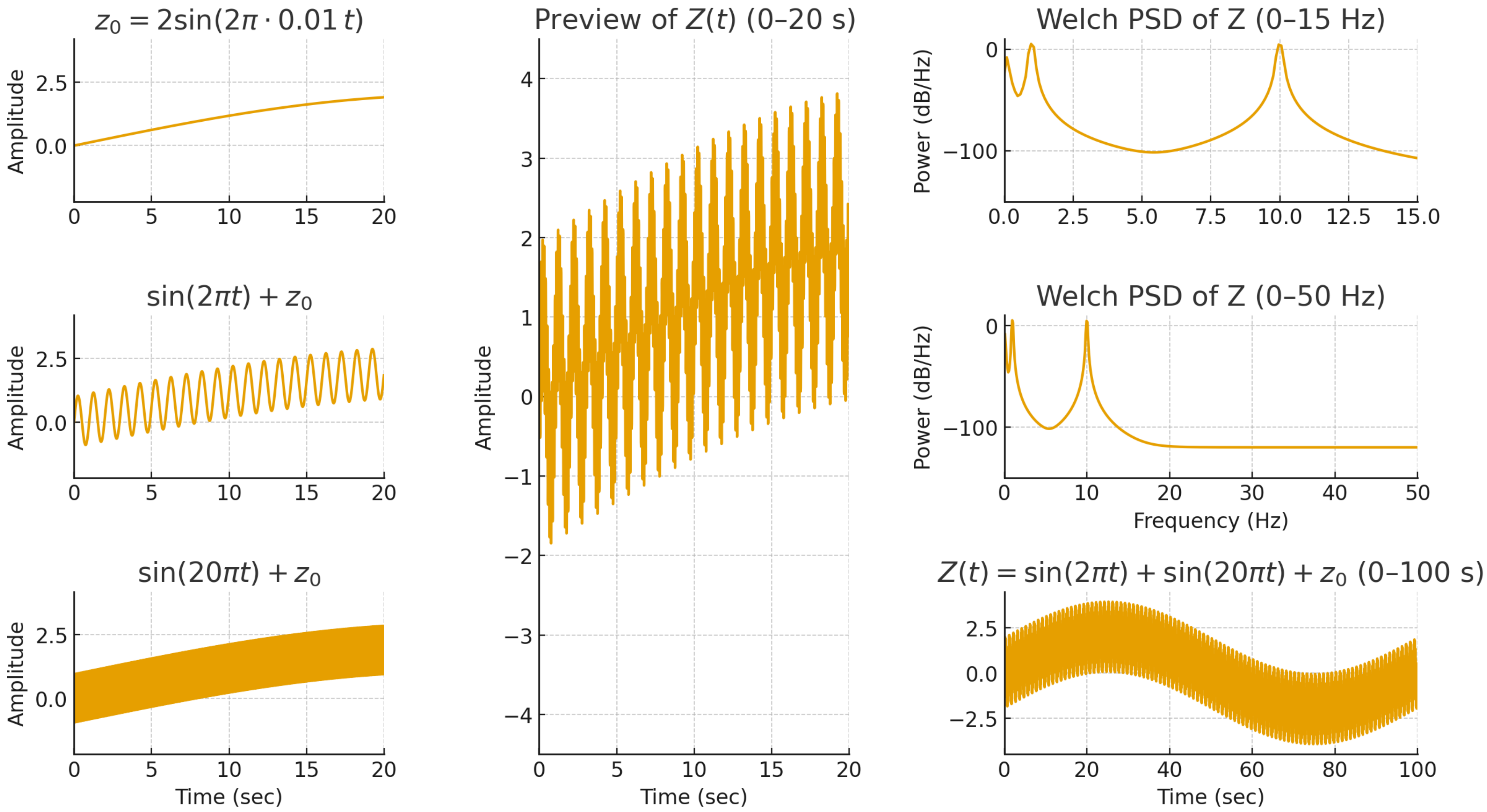
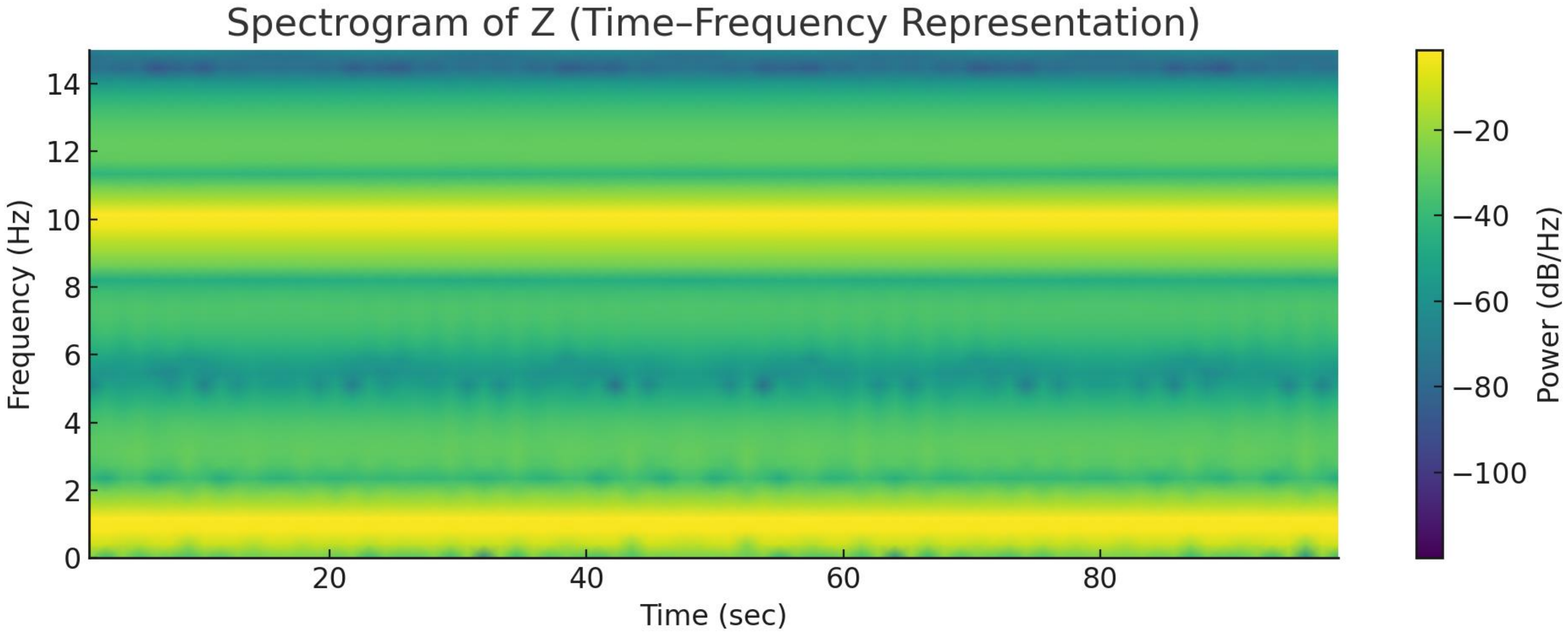
When Frequencies Change



Spectrogram: Time-Frequency representation



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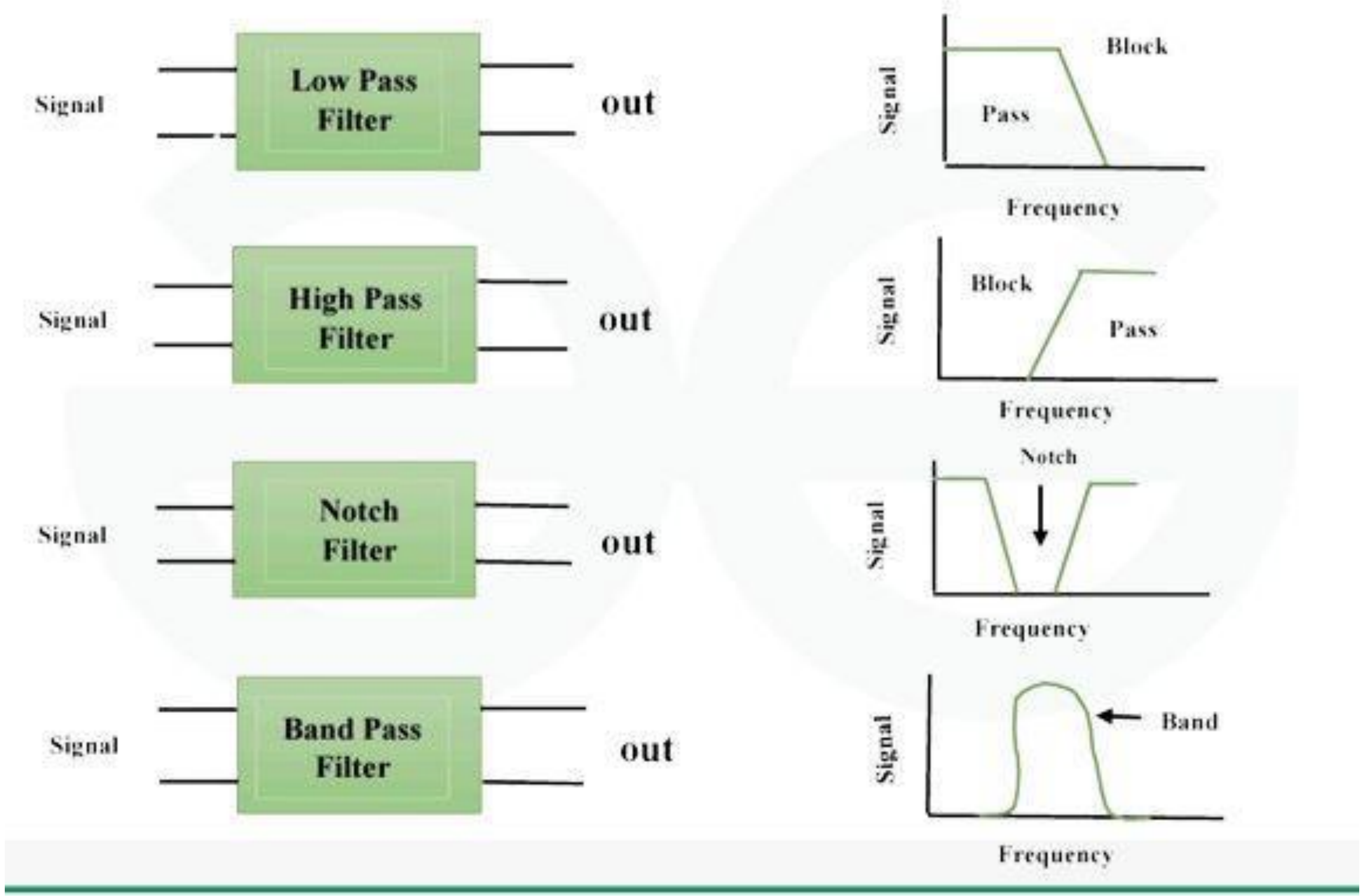
Filtering: How We Clean, Focus, and Reveal the True Signal

“Mathematical operations that attenuate the amplitude of a subset of frequencies in the signal.”
→ “Attenuate” means **reduce strength or remove power** at those frequencies.



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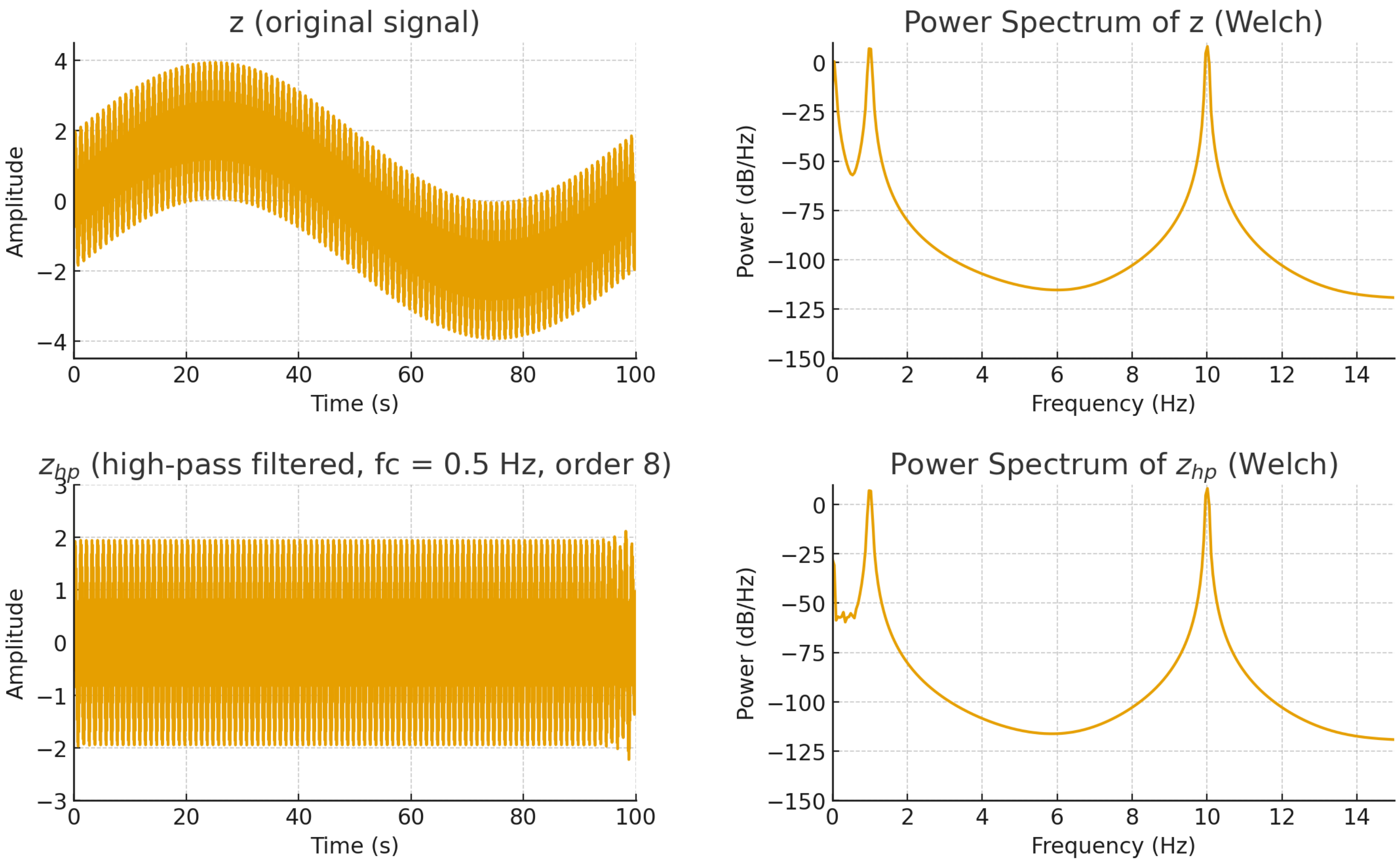
High Pass Filtering

highpass(Z, 0.5, 100, Steepness=0.95)



High-pass filters remove **slow drifts** and preserve **fast dynamics**.
This is essential in real-world data (e.g., tremor signals, accelerometer readings, EEG) to eliminate slow baseline fluctuations due to posture, movement, or sensor drift. Filtering helps us **focus on the meaningful activity frequencies** while cleaning up the noise or trend.

Low Pass Filtering: A moving average

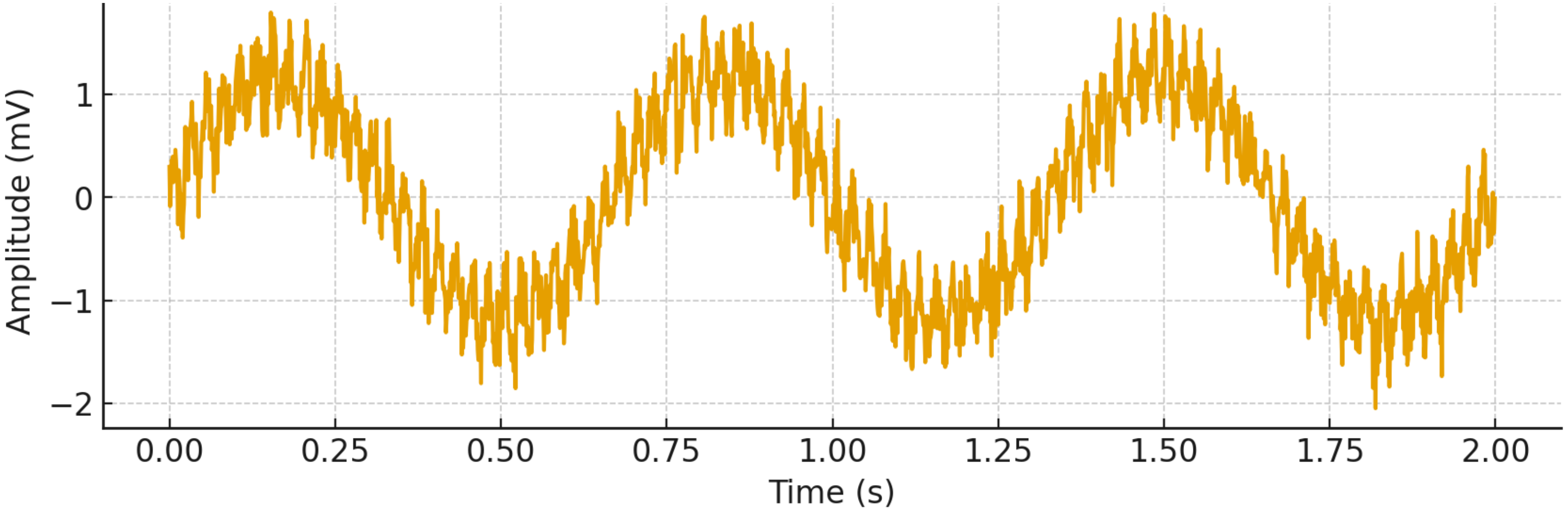
A **moving average** is a way to **smooth a signal** — to make it less noisy and easier to see the main trend.

A **moving average** replaces each sample by the **average of its neighbors**:

$$y[n] = \frac{1}{k} \sum_{i=0}^{k-1} x[n-i]$$

That operation is exactly the same as a **convolution** between:

- your signal $x[n]$, and
- a small kernel $h[n] = \frac{1}{k}[1, 1, 1, ..., 1]$.



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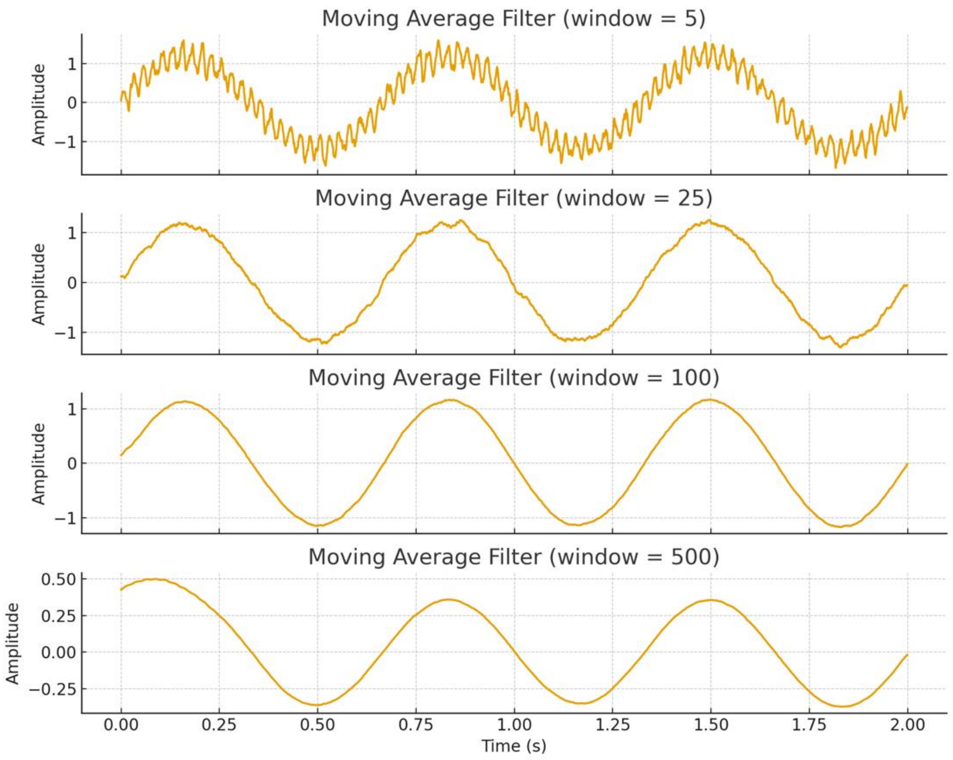
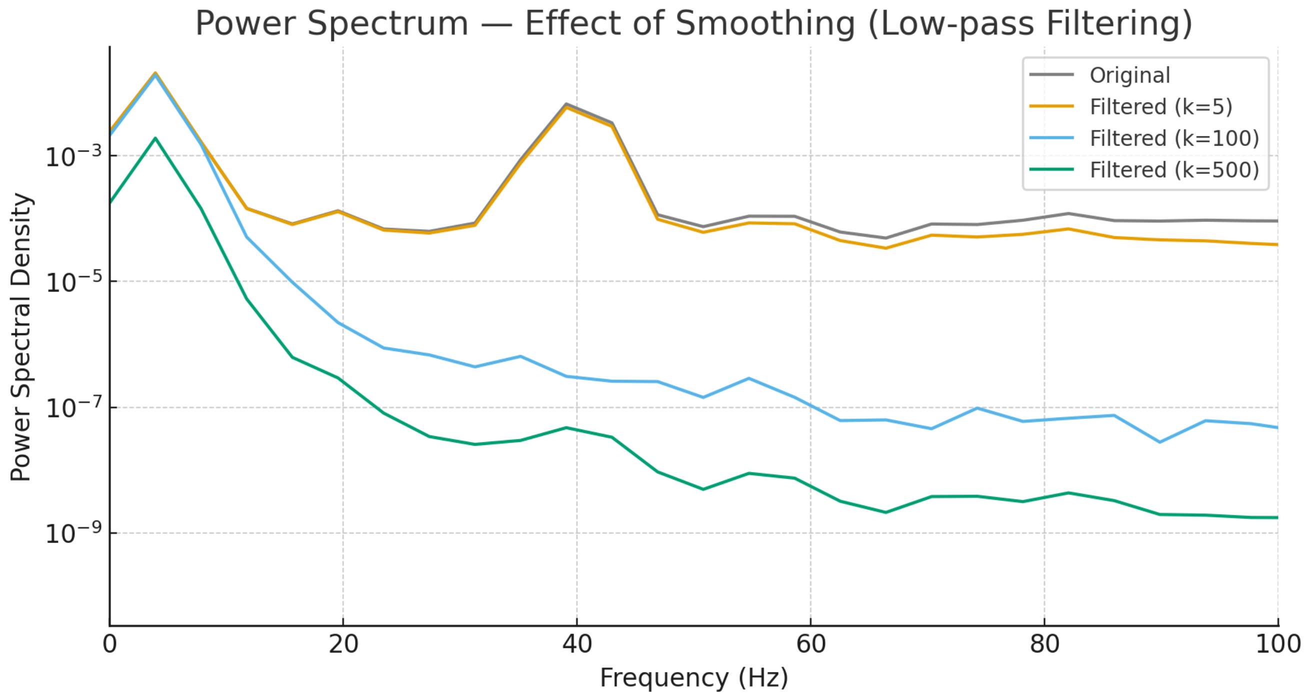
Low Pass Filtering: A moving average





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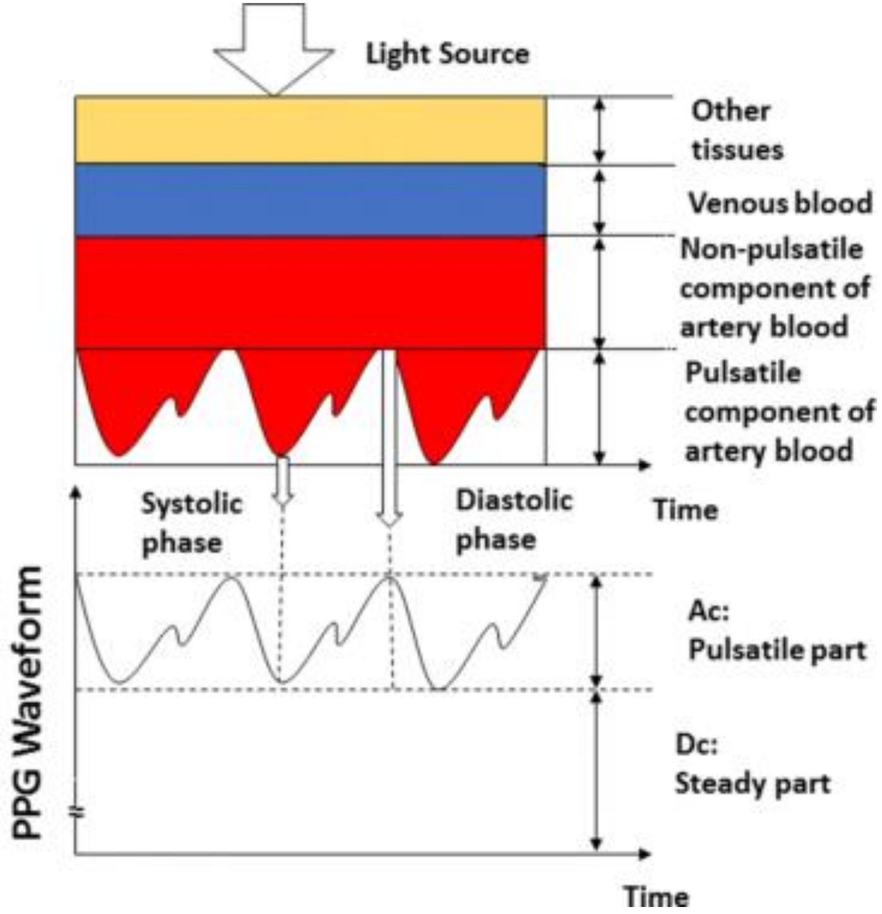
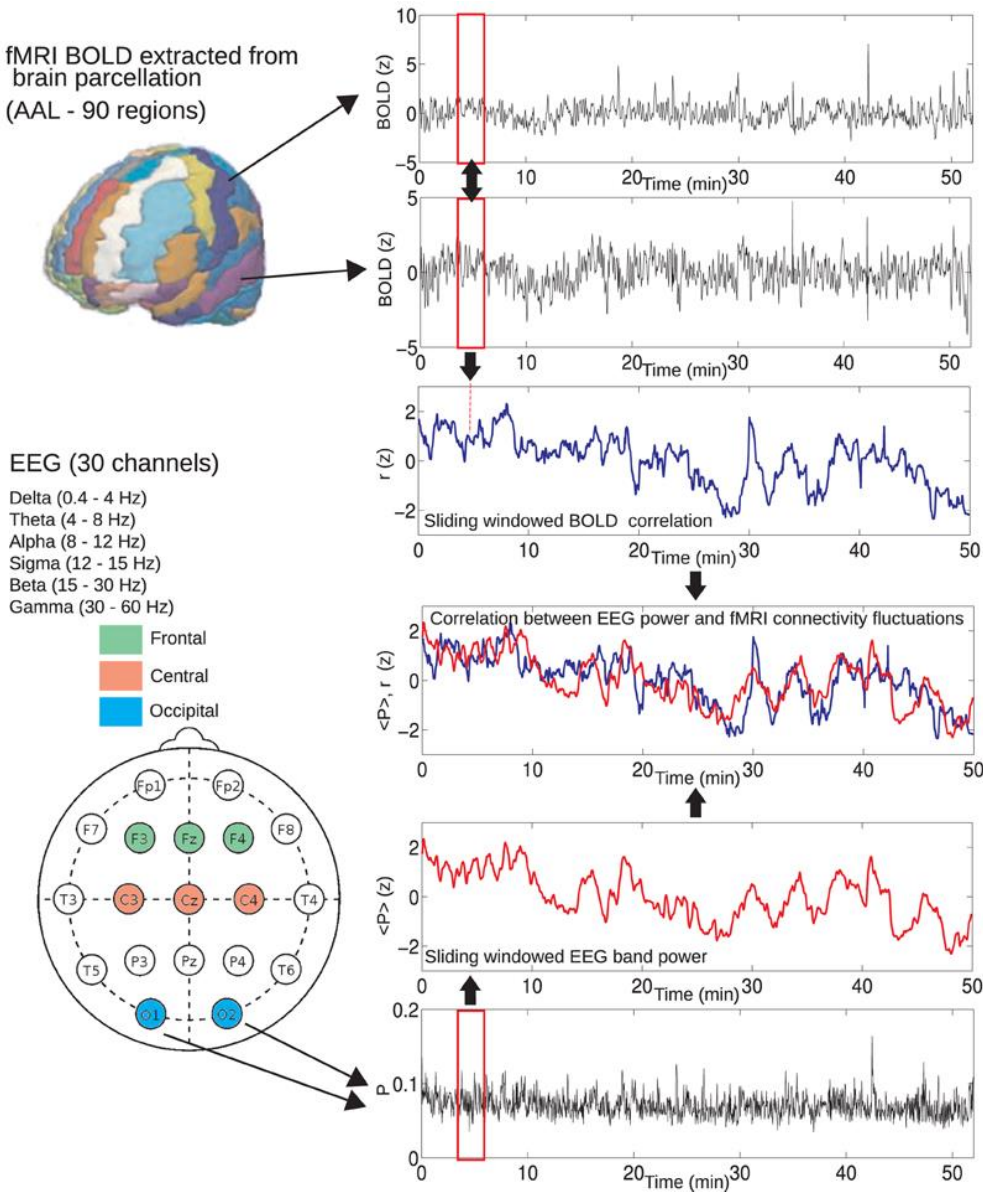
Beyond IMU - Smartwatch

Multi-sensor device:
Accelerometer
Ambient temperature
Gyroscope
Humidity
Photoplethysmography (PPG)

verily



Beyond Smartwatch: Time-Serie Data very common in Neuroscience



Let’s Code

Group 1	Group 2	Group 3	Group 4	Group 5	Group 6	Group 7	Group 8
Philip Press	Viola Ceriani	Duru Okay	Yossra Serroukh	Harsimran Kaur	Jenna Lin	Muireann Hogan	Lucia Jing
Margarida Neves	Anya Kaur Haddon	Chloe Kam	Rebekah Bourne	Luca Pastorello	Mustafa Gunaydin	Edona Bajrami	Zishan Lin
Olivia Pownall	Anais Chia	Wenbo Liao	Hattie Oliver	Luoyuan Zhang	Laura Rakiec	Francesca Murley-Holme	Stephanie Sun
Charlotte Yu	Shobana Chandrashekar	Yunyi Gao	Thishany Kuganeswaran	Ellie Carre	Hanna Altessaid	Ruben Thiagarajah-Fernar	Neera Gahir
Chun Hei Leung	Katie Hay	Anas Saleem	Hanyue Pang	Veronika Shevchenko	Alisija Dabasinskaite	Felix Varenne	Chuyi Zhang
Andrea Fan	Nina Jeffrey	Chi U Chau	Zeinab Ben Halim	Amina Bououdine	Ema Ferra	Ruofan CAO	Lili Yassin
Adelina Shahata	Asma Abdullahi	YINUO Wang	Isabella Coloru	Krystal Tan	Temi Lana	Xinrui Fan	Keya Tanwani
Tanaka Udugama Jal	Vea Bley	Mari Hronska	Lucas Yebra Garcia	Sarah Kurbanov			

https://github.com/Sandoretal/Module_3/tree/main/tutorial_3