Detection of Parkinson’s Disease Using Automated Tunable Q Wavelet Transform (A-TQWT) Technique with EEG Signals

Digital Signal Processing

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Parkinson's Disease

- **Parkinson's disease** is a brain disorder that causes unintended or uncontrollable movements, such as shaking, stiffness, and difficulty with balance and coordination.

- It affects the **nervous system** and the parts of the body controlled by the nerves.

- It is a **neurodegenerative disorder** that affects predominately the dopamine-producing ("dopaminergic") neurons in a specific area of the brain called **substantia nigra.**

Symptoms of Parkinson’s Disease

- Involuntary shaking of particular parts of the body such as hands, arms, legs, jaw, or head (tremor).
- Slow movement.
- Depression and anxiety.
- Balance problems.
- Loss of sense of smell (anosmia).
- Memory problems.

Diagnosis and Detection of the Parkinson’s Disease

- **Interviewing and questionnaire method**
  - Interviewing and questionnaire methods by trained neurologists are time-consuming, burdensome and prone to errors.
- **Voice based methods**
  - The performance of voice-based methods are limited and can be altered intentionally.

Diagnosis and detection of the Parkinson's Disease

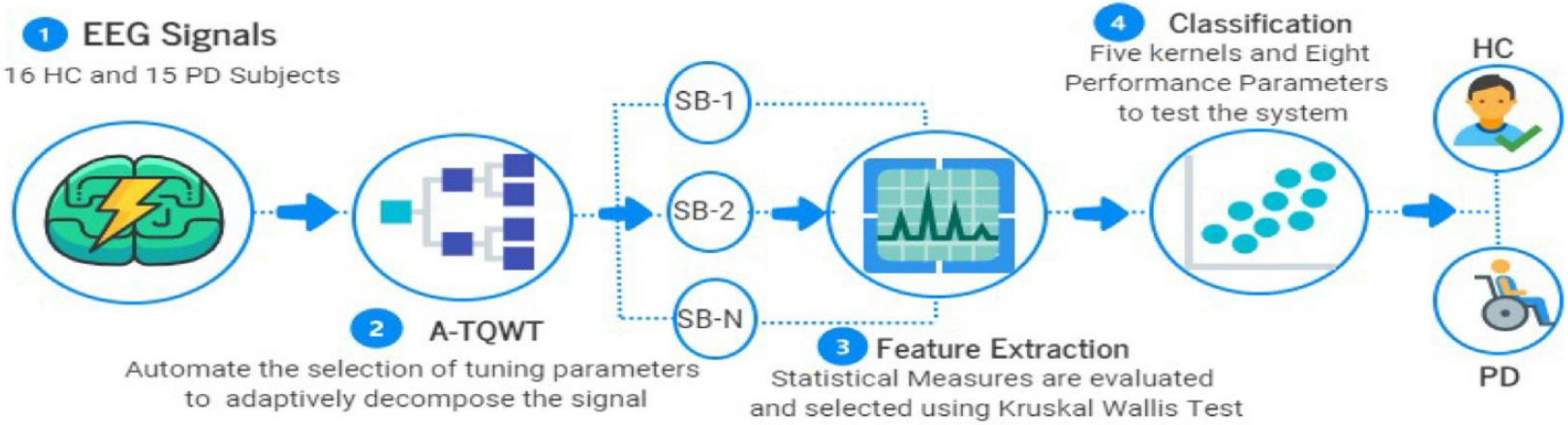
- **Neuroimaging methods**
  - Computed Tomography, PET Imaging, and Functional MRI.
  - It require additional recordings, time-consuming, costly and radio-active as compared to signal processing techniques.

- **Signal Processing methods**
  - Electrocardiography(ECG), Electromyography (EMG), and Electroencephalography (EEG).
  - The detection of PD using ECG and EMG signals has been accomplished but **offers limited success** in terms of classification accuracy.
  - EEG signals have **yielded high performance** in the detection of PD even with its low amplitude.

Techniques for Identifying PD Using EEG Signal

- Fast Fourier Transform (FFT).
- Analysis of Variance (ANOVA) with Fast Fourier Transform (FFT).
- Discrete Wavelet Transform (DWT).
- Discrete Wavelet Transform (DWT) and Fast Fourier Transform (FFT).
- **Tunable Q-Wavelet Transform (TQWT).**

Proposed Method



Flow Chart of the Proposed Method.

Wavelet Transform (WT)

- A **Wavelet** is a **wave-like oscillation** that is localized in time.
- It has average value of zero.

Wavelet

Wavelet Equation

$$\psi_{a,b}(t) = \frac{1}{\sqrt{a}}\,\psi\left(\frac{t-b}{a}\right) \quad a, b \in \mathbf{R}$$

where,

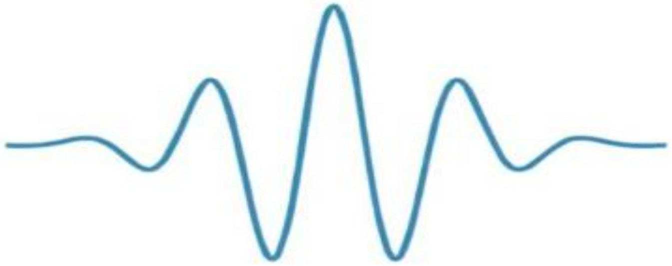
a = Scaling (Dilation) Factor.

b = Shifting (Translation) Factor.

Wavelet Transform (WT)

[a>1]

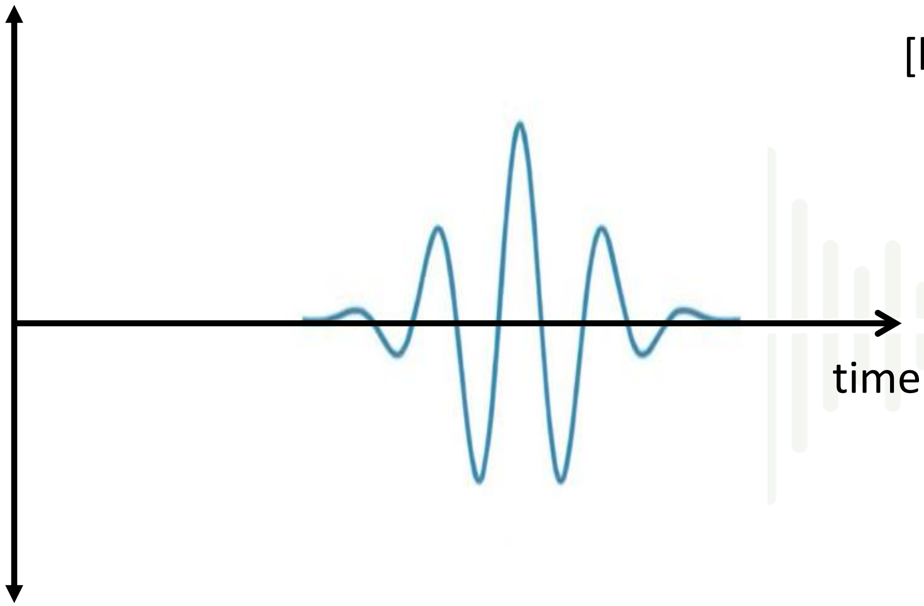
Compressed Wavelet for Extracting
High Frequency Component



[0<a<1]

Stretched Wavelet for Extracting
Low Frequency Component

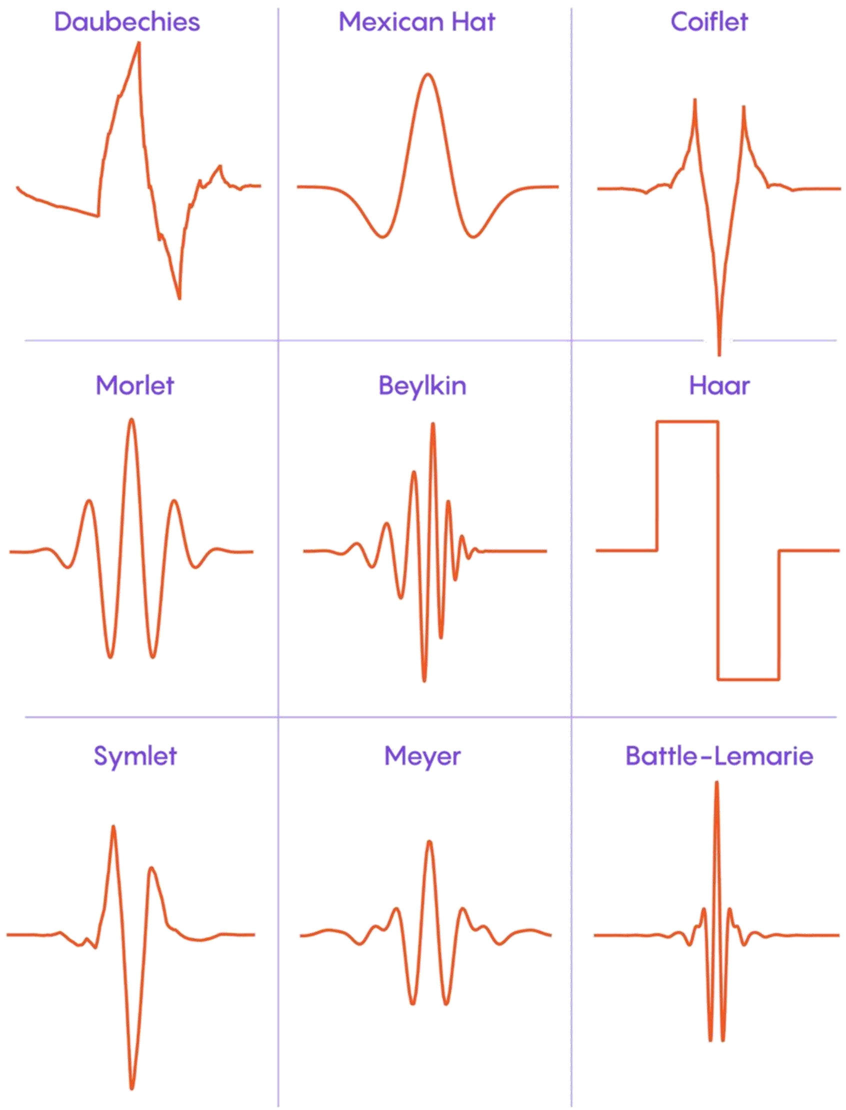
[b>0]



Right Shifted Wavelet

Wavelet Transform (WT)

- Different types of wavelets



Wavelet Transform (WT)

- The **wavelet transform** is a mathematical technique which can **decompose a signal into multiple lower resolution levels** by **controlling the scaling and shifting factors** of a single wavelet function (also called "mother wavelet").

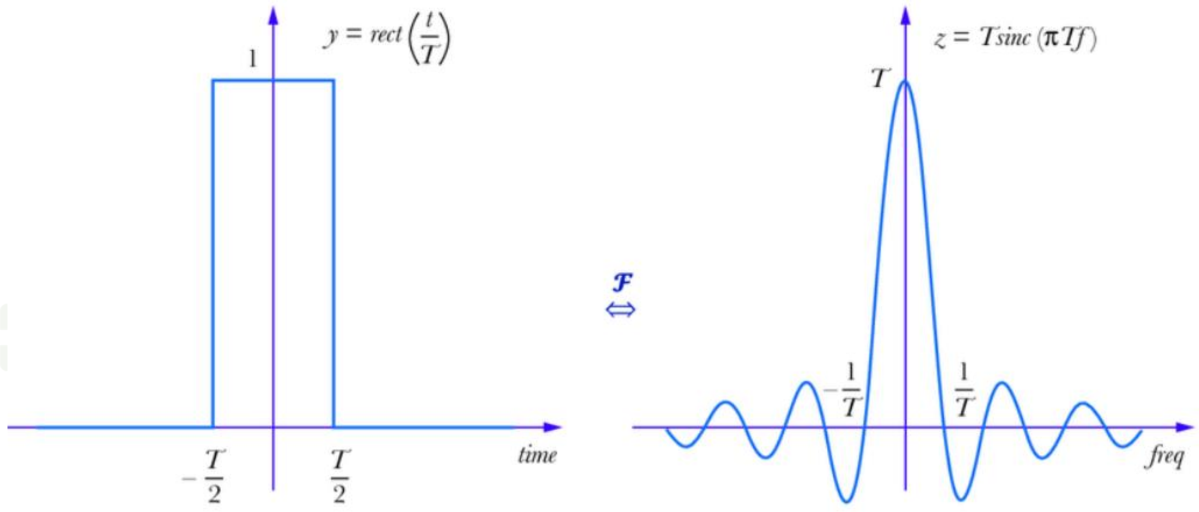
- **Equation for Continuous Wavelet Transform**

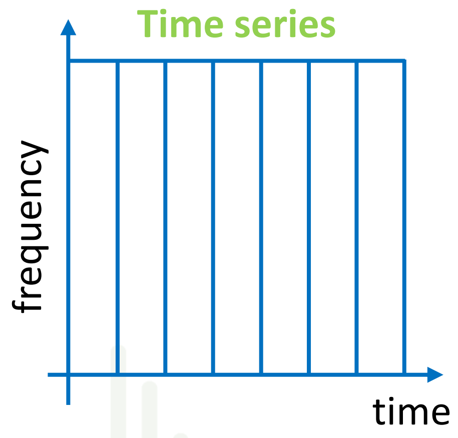
$$T(a,b) = \frac{1}{\sqrt{a}} \int_{-\infty}^{\infty} x(t)\, \psi^* \left(\frac{t-b}{a}\right)\, dt$$

where,
x(t) = Input/Main Signal.
a = Scaling Parameter.
b = Shifting Parameter.

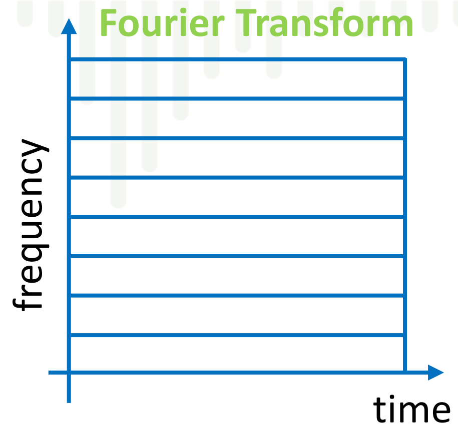
Wavelet Transform (WT) vs Fourier Transform (FT)

- Fourier Transform of a Rectangular Pulse





High time resolution
Zero frequency resolution



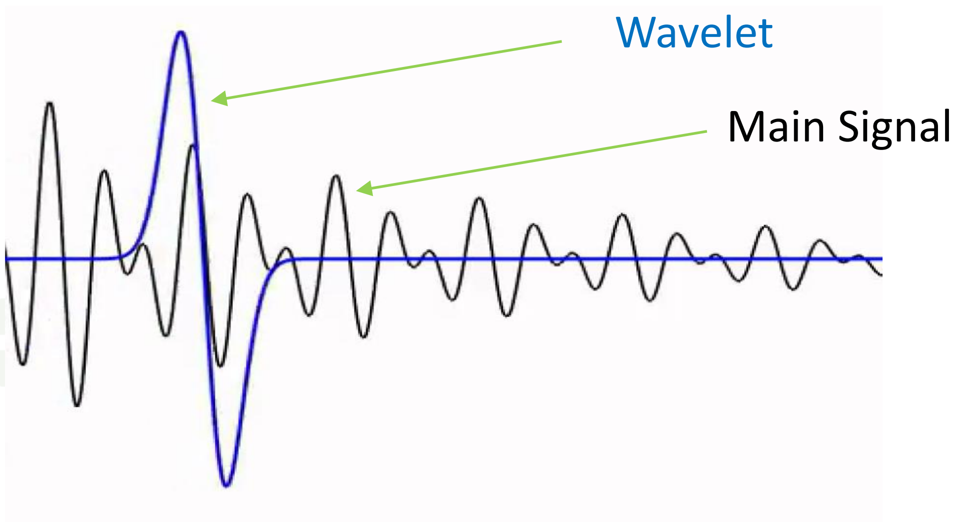
High frequency resolution
Zero time resolution

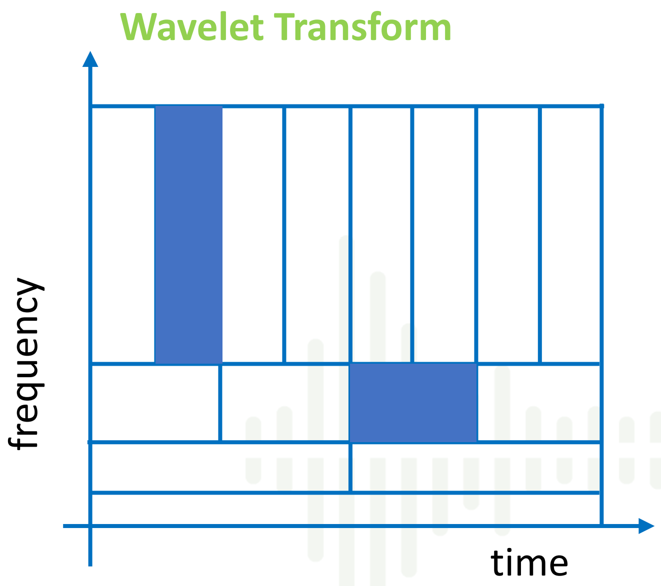
➢ Fourier Transform (FT) provides global frequency information.

➢ Either time or frequency can be known at a specific point.

Wavelet Transform (WT) vs Fourier Transform (FT)

- Wavelet Transform

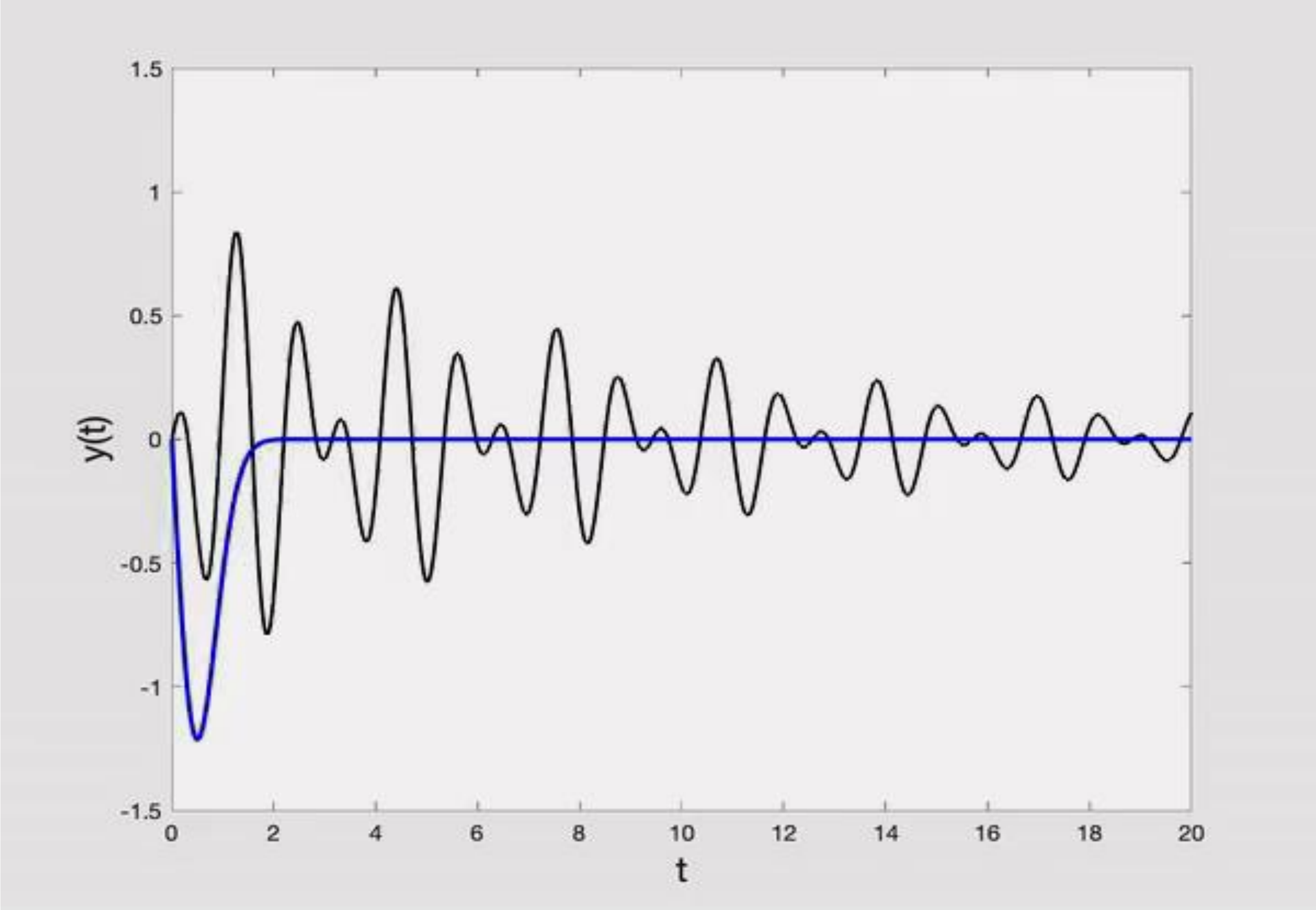




- ➢ Wavelet Transform (WT) provides specific frequency information.
- ➢ Both time or frequency can be known at a specific point.
- ➢ For small frequency values a high resolution in the frequency domain, low resolution in the time- domain.
- ➢ For large frequency values a low resolution in the frequency domain, high resolution in the time domain.

Feature Capturing Using Wavelet Transform

- It is like a **convolution operation**.
- Input signal is fixed while **wavelet is moving** from left to right.



Discrete Wavelet Transforms (DWT)

- For Continuous Wavelet Transform, scaling (a) and translation (b) are selected for every possible point which create a huge amount of data.
- Therefore, we can only consider the discreet points of scaling (a) and translation (b) parameters for small amount of data.
- **Discrete Wavelet**

$$\psi_{m,n}(k) = a_0^{-\frac{m}{2}} \psi(a_0^{-m}(k - nb_0 a_0^m))$$

$$\begin{cases} a = a_0^m & [\, a_0 > 1, \ \text{m = width}] \\ b = nb_0 a_0^m & [b_0 > 0] \end{cases}$$

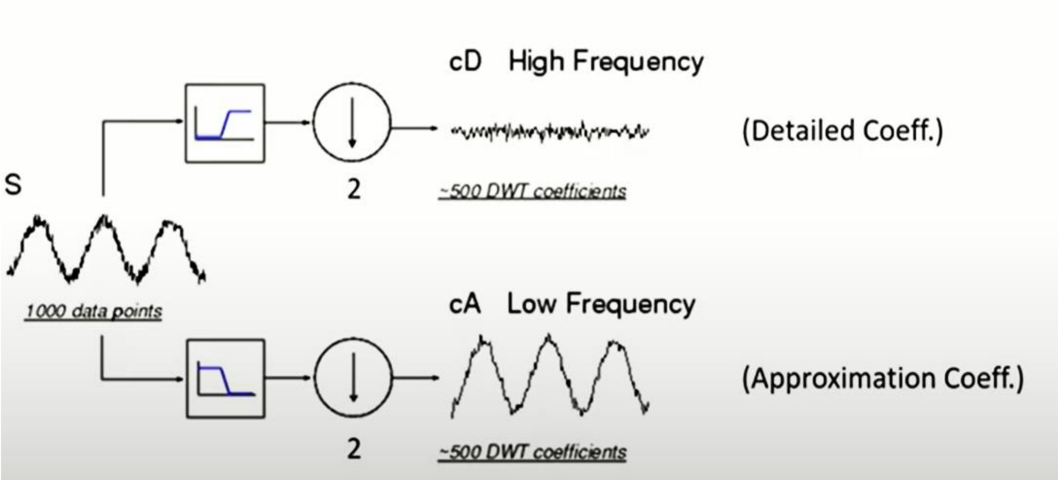
* Narrow wavelet is translated by small steps.

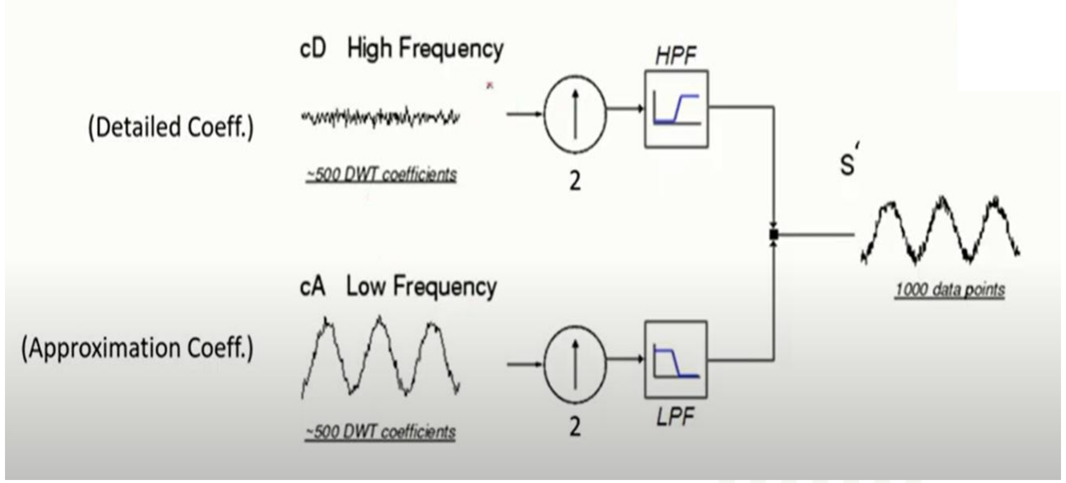
* Wide wavelet is translated by large steps.

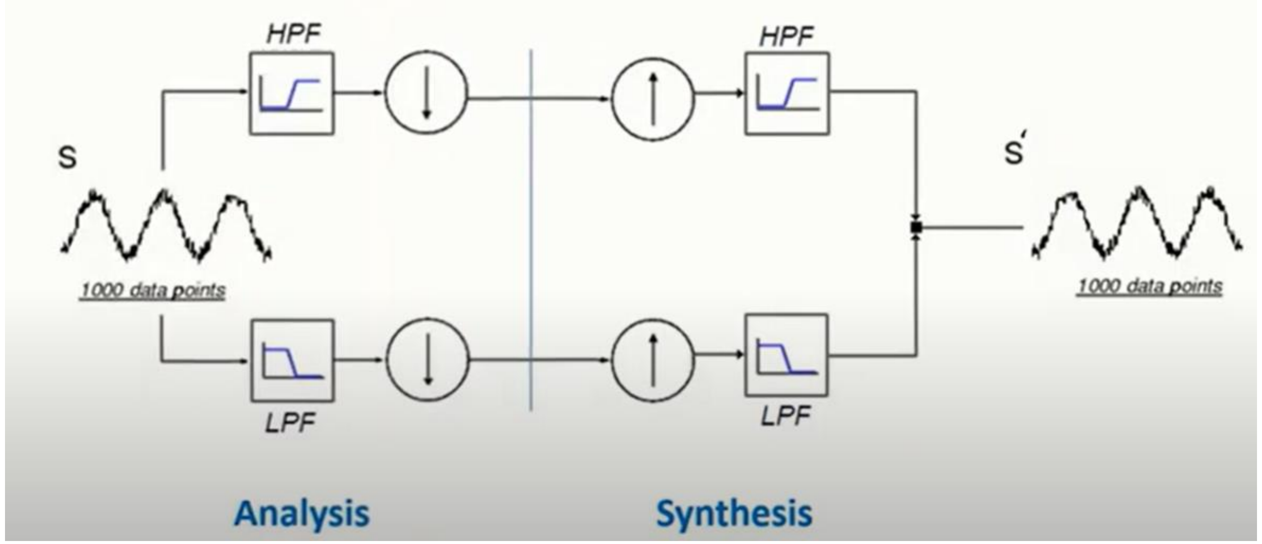
- **Discrete Wavelet Transform**

$$DWT(m,n) = f < f, \psi_{m,n} > = a_0^{-\frac{m}{2}} \sum_{k=-\infty}^{\infty} f(k) . \psi^*(a_0^{-m}(k - nb_0))$$

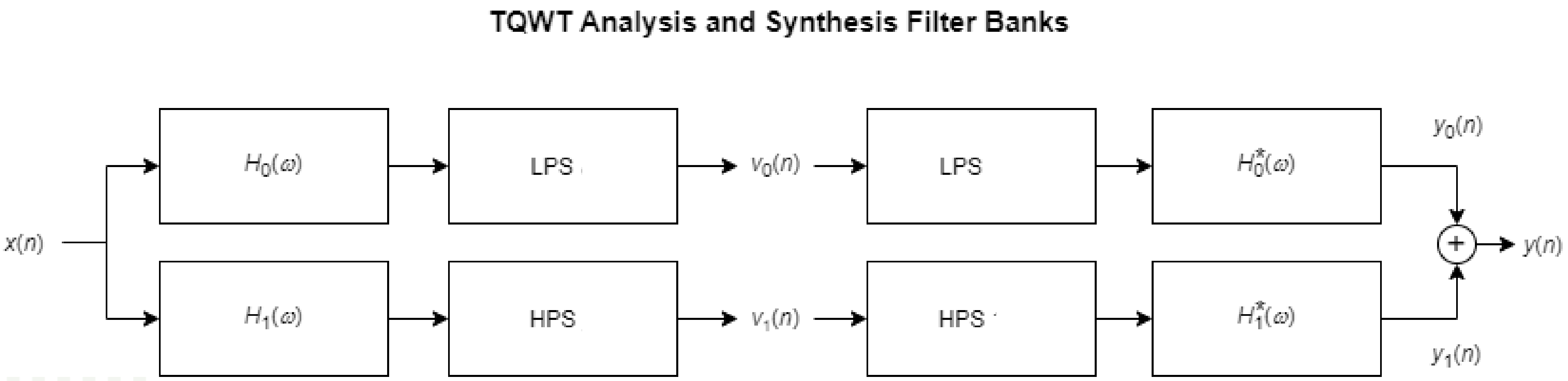
Wavelet Transform: Filter Bank







Tunable Q Wavelet Transform Filter Bank



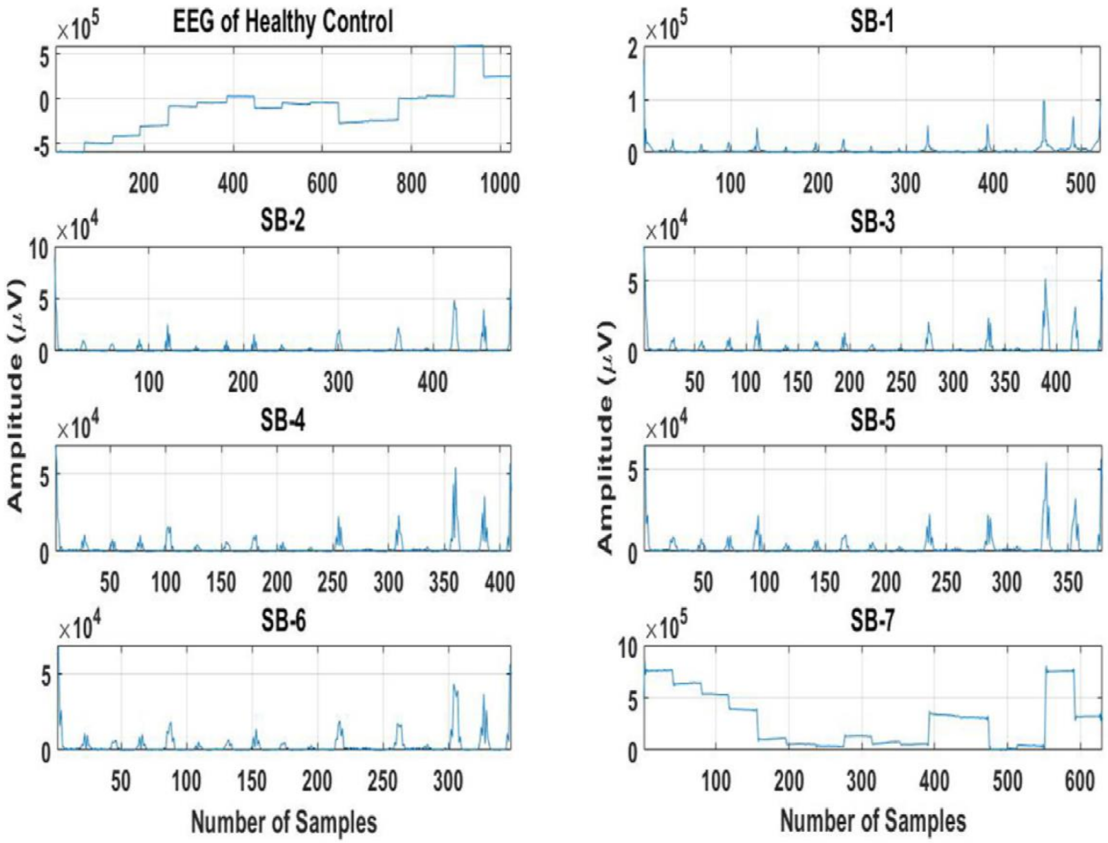
Redundancy Rate: $\rho = \frac{\xi}{1-\psi}$

Quality Factor: $Q = \frac{2-\xi}{\xi}$

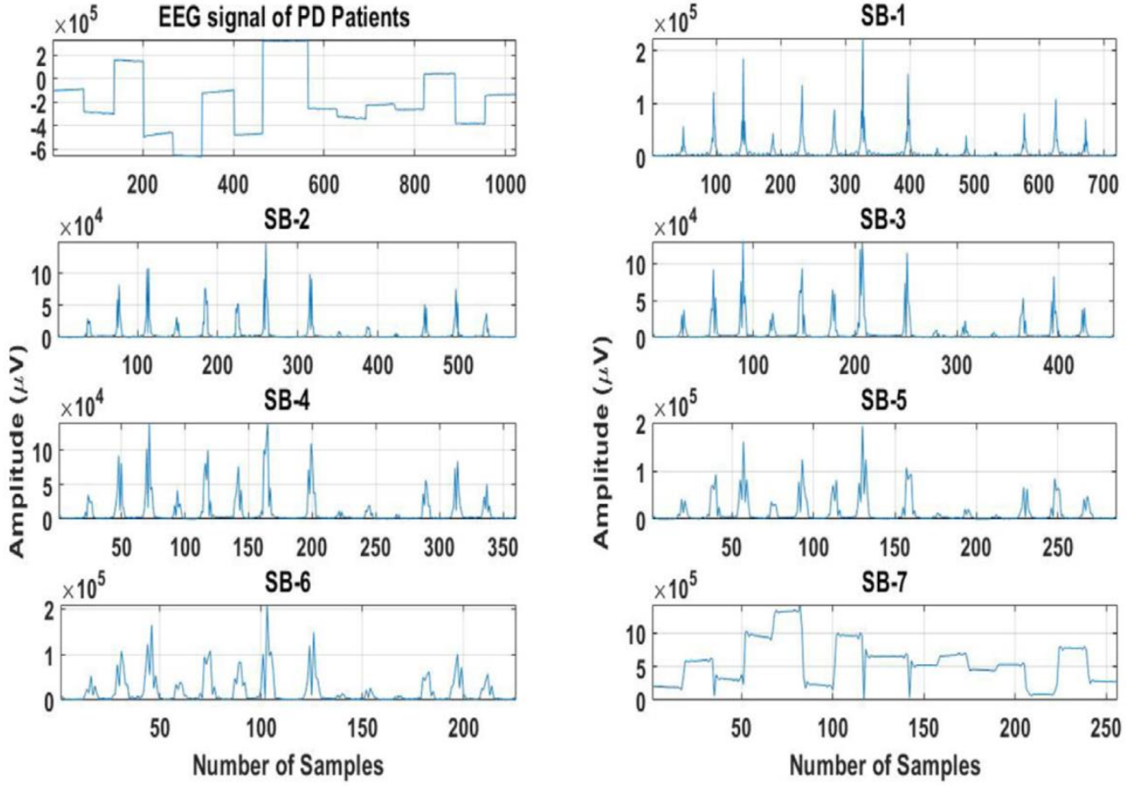
Maximum Number of Levels: $R_{max} = \left\lfloor \frac{\log\left(\frac{N}{4(Q+1)}\right)}{\log\left(\frac{Q+1}{Q+1-\frac{2}{\rho}}\right)} \right\rfloor$

* LPS: Low Pass Scaling (ψ), HPS: High Pass Scaling (ξ), Number of Sample (N)

A-TQWT Signal Decompositions

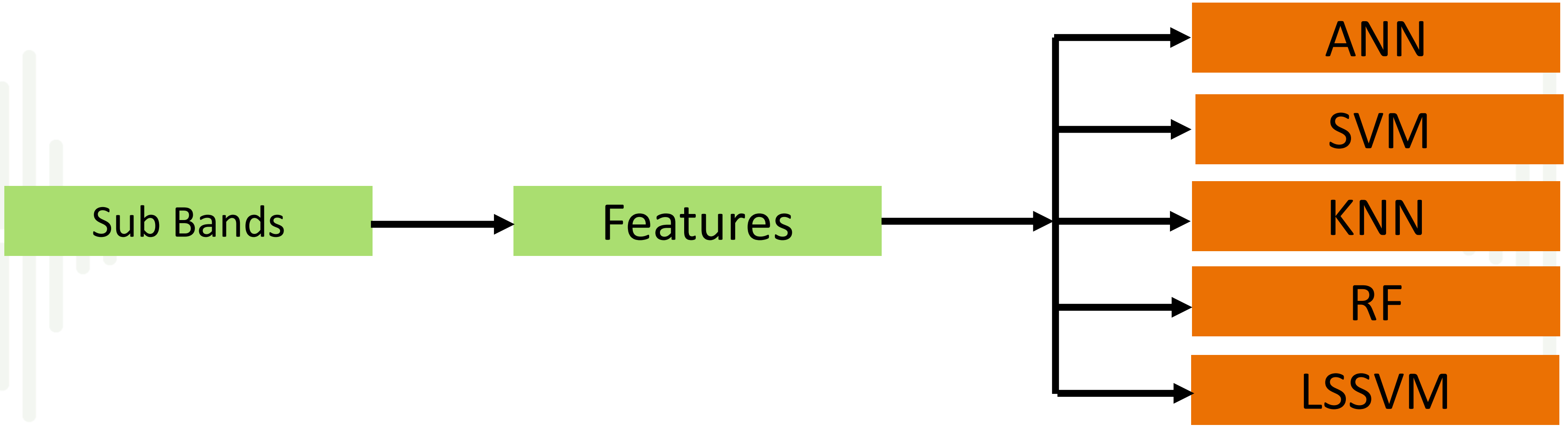


Typical EEG signals: (a) HC subject, and (b) its ATQWT sub-bands.



Typical EEG signals (a) PD subject, and (b) its ATQWT sub-bands

Classification



Performance Analysis

Table-1: Comparison of average errors obtained due to TQWT and A-TQWT techniques.

Class	TQWT	A-TQWT
HC	0.0491	**3.88×10^{-06}**
SF	0.0456	**1.78×10^{-05}**
SO	0.08903	**1.10×10^{-06}**

* HC: Health Control
* SF: PD [Off Medication]
* SO: PD[On Medication]

Performance Analysis

Table-2: Summary of comparison for automated detection of PD with state-of-the-art techniques.

Authors	Dataset	Method	Classifier	ACC(%)
[1]	Speech	WT, MFCC	SVM	86.64
[2]	EEG	WT	LDD	79.16
[3]	EEG	FFT	RNN	74
[4]	EEG	TVD	SVM	94.34
Proposed	EEG	A-TQWT	LSSVM	**97.65, 96.13**

Conclusion

- The proposed A-TQWT provides representative decomposition and reconstruction for signal analysis and synthesis.

- The proposed combination of A-TQWT and LSSVM is so effective that it outperforms existing speech, motions, and EEG-based state-of-the-art techniques.

- In future, the proposed method can be used to detect other neurological disorders like autism, Alzheimer’s disease, attention deficit hyperactivity disorder and insomnia.

References

1] K. Smith, B. Varun, A. U. Rajendra, “Detection of Parkinson’s disease using automated tunable Q wavelet transform technique with EEG signals,” *Journal of Biocybernetics and Biomedical Engineering,* vol. 41, pp. 679-689, 2021.

[2] O. Wei, H. Basah, H. Lee, V. Vijean, “Empirical Wavelet Transform Based Features for Classification of Parkinson’s Disease Severity,” *Journal of Medical Systems,* vol. 42, no. 12, 2017.

[3] T. B. Drissi, S. Zayrit, B. Nsiri, “Ammoummou A. Diagnosis of Parkinson’s Disease Based on Wavelet Transform and Mel Frequency Cepstral Coefficients,” *International Journal Adv Computer Science Application, vol. 10 no. 3,* 2019.

Thank You