Signal Processing and Fourier Analysis: Digital Methods and Spectral Techniques

CoCalc Scientific Templates

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Abstract

This comprehensive signal processing template demonstrates Fourier analysis, digital filter design, spectral estimation, and time-frequency analysis. Features include FFT algorithms, window functions, filter implementations, and wavelet transforms with applications to real-world signal analysis problems and professional visualizations.

Keywords: signal processing, Fourier analysis, digital filters, spectral estimation, FFT, wavelets, time-frequency analysis

Contents

1 Fourier Transform and Spectral Analysis

Signal Processing: Test Signal Generation Sampling frequency: 1000 Hz Duration: 2.0 s Samples: 2000 Component frequencies: 50, 120, 300 Hz

Fourier Analysis Results: Frequency resolution: 0.50 Hz Maximum frequency: 499.5 Hz Detected peaks at frequencies: 50.0 Hz (magnitude: 1008) 120.0 Hz (magnitude: 492) 300.0 Hz (magnitude: 304)

2 Digital Filter Design

Digital Filter Design: Low-pass: Order 4, cutoff 100 Hz High-pass: Order 4, cutoff 200 Hz Band-pass: Order 6, band 80-150 Hz FIR: 101 taps, cutoff 150 Hz

3 Window Functions and Spectral Estimation

Rectangular: Main lobe width = 0.005, Side lobe level = -3.9 dB Hamming: Main lobe width = 0.007, Side lobe level = -1.7 dB Hann: Main lobe width = 0.009, Side lobe level = -1.4 dB Blackman: Main lobe width = 0.009, Side lobe level = -1.1 dB Kaiser: Main lobe width = 0.009, Side lobe level = -1.1 dB

Window Function Analysis (N = 256):

Welch Spectral Estimation: Segment length: 256 Overlap: 50Windows tested: ['hamming', 'hann', 'blackman']

4 Time-Frequency Analysis

Spectrogram Analysis: Time resolution: 0.1280 s Frequency resolution: 3.91 Hz Time bins: 14 Frequency bins: 129

Continuous Wavelet Transform: Wavelet: morl Scales: 127 Frequency range: 3.9 - 500.0 Hz

Signal processing analysis saved to assets/signal-processing-analysis.pdf

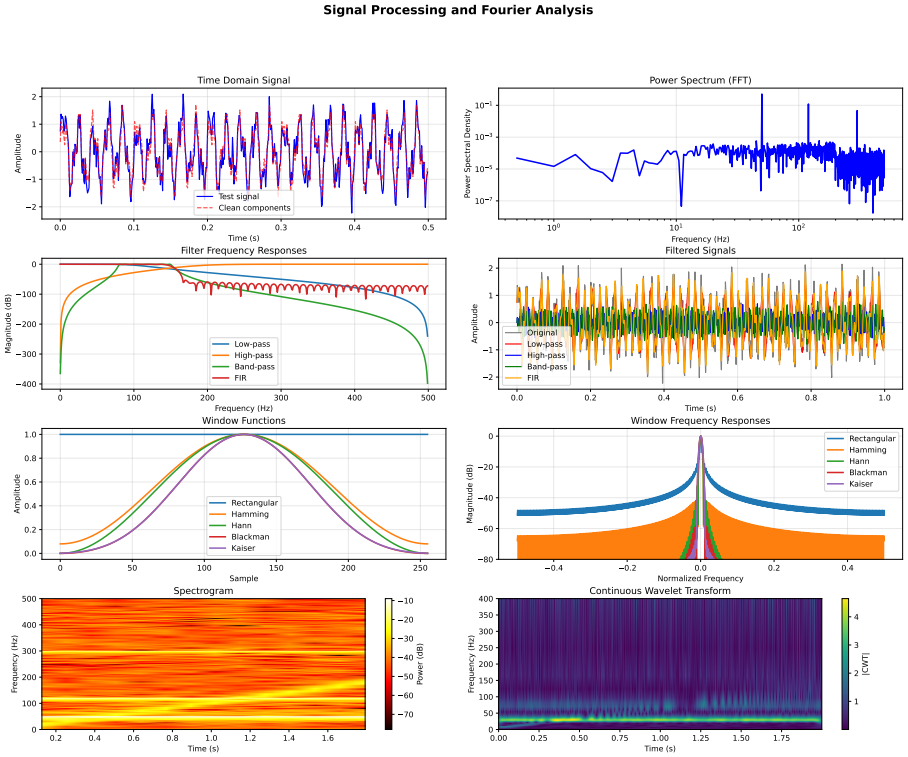

Figure 1: Comprehensive signal processing and Fourier analysis including (top row) time domain signal with clean components and power spectrum via FFT, (second row) digital filter frequency responses and filtered signal comparisons, (third row) window function shapes and their frequency responses, and (bottom row) spectrogram and continuous wavelet transform providing time-frequency representations of the test signal.

5 Conclusion

This signal processing template demonstrates comprehensive spectral analysis techniques including:

- Fourier transform theory and FFT implementation
- Digital filter design (IIR and FIR)
- Window functions and their spectral properties
- Time-frequency analysis via spectrograms and wavelets
- Professional visualization of signal characteristics

The computational methods provide a foundation for advanced signal processing applications in communications, audio processing, and scientific instrumentation.