LabVIEW Tools for Time-Frequency, Time-Series, and Wavelet Analysis

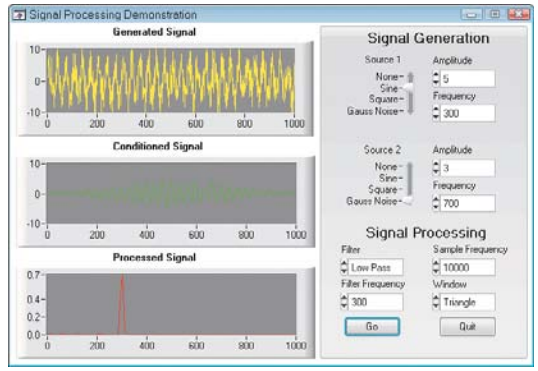
NI Advanced Signal Processing Toolkit

Time-Frequency Analysis
- Interactive Express VI for joint time-frequency analysis (JTFA)
- Quadratic JTFA algorithms
- Gabor transform and Gabor expansion
- Time-varying filter Express VI

Time-Series Analysis
- Multidimension statistical algorithms
- Spectral estimation algorithms
- Cepstrum and power spectrum filtering
- AR, MA, and ARMA modeling and prediction
- Modal analysis algorithms

Wavelet Analysis
- Interactive Express VI for graphical wavelet design, 1D and 2D multiresolution analysis
- Continuous wavelet transform, discrete wavelet transform, undecimated wavelet transform, and wavelet packet
- Wavelet-based application VIs including peak detection, denoise, trend removal, and edge detection

Operating Systems
- Windows Vista/XP/2000



Overview

The NI Advanced Signal Processing Toolkit is a suite of Express VIs, library VIs, and example programs for time-frequency, time-series, and wavelet analysis. With this toolkit, you can experiment and develop with modern analysis techniques that include JTFA, spectral estimation, cepstrum, modeling, multidimension statistical analysis, and wavelet analysis.

You can use these functions for offline and online analyses based on LabVIEW and for real-time deterministic applications using the LabVIEW Real-Time Module. In addition, you can use some functions in NI LabWindows™/CVI software.

Time-Frequency Analysis

Time-frequency analysis VIs in the Advanced Signal Processing Toolkit include algorithms and tools you can use to characterize how the spectral content of signals evolves over time. This technique can reveal information that is not immediately obvious with standard frequency analysis tools such as a fast Fourier transform (FFT)-based spectrum.

The toolkit includes the following time-frequency analysis algorithms/tools:

- Time Frequency Analysis Express VI
- Short-time Fourier transform (STFT)
- Wigner-Ville distribution (WVD)
- Gabor spectrogram
- Adaptive spectrogram
- Cohen's class
- Choi-Williams distribution (CWD)
- Cone-shaped distribution
- Gabor transform/expansion
- Time-varying filter
- Dual function

Engineers usually implement time-frequency analysis algorithms to analyze time-varying signals whose frequency components evolve over time. Some common time-varying signals include biosignal, sound and vibration signals, and seismic signals. You can use the Time Frequency Analysis Express VIs to reduce noise, understand the time-varying characteristics of the signals, and extract features.

Time-Series Analysis

A time series is a sequence of data points that are sampled in successive time instances. Time series and time-series analysis are common in economics. Economists use time-series analysis algorithms to make forecasts for economic principles based on the statistics of time series or models that fit the time series. For example, analysts make forecasts for stock prices based on the past performance of the stocks. In test and measurement applications, the discrete signals you measure with NI data acquisition devices are also time series. A time series usually contains underlying information about the physical system that generates the time series. Time-series analysis helps you understand the underlying structure or behavior of a physical system.

Generally speaking, most signal analysis and processing algorithms are incorporated in time-series analysis algorithms, including time-frequency and wavelet analysis. In the Advanced Signal Processing Toolkit, time-frequency and wavelet analysis are separated from time-series analysis because they are well-established, advanced signal processing algorithm categories and might involve other applications such as image processing.

There are mainly three categories of time-series analysis algorithms in this toolkit. They are statistical analysis, spectral estimation, and modeling.

Use statistical analysis VIs to understand correlation and the variation of univariable time series as well as to remove the redundancy of multivariable time series. The toolkit includes the following statistical analysis algorithms:

- Mean, variance, skewness, kurtosis, and entropy
- Covariance matrix or correlation matrix
- Principal component analysis (PCA)
- Independent component analysis (ICA)

Use the spectral estimation VIs to analyze signals in the frequency domain. The toolkit includes the following spectral estimation algorithms:

- Periodogram
- Welch
- AR spectrum
- ARMA spectrum
- Multiple signal classification (MUSIC)
- Bispectrum
- Cepstrum

Periodogram and Welch are FFT-based methods. AR spectrum, ARMA spectrum, and MUSIC are model-based methods. Use model-based methods, which produce high-resolution spectra, when a signal has a small number of samples. Use bispectrum, which is the second-order spectrum algorithm, to understand the correlation between frequencies and components. Use cepstrum, which is the spectrum of a spectrum, to identify the presence of harmonics or separate series of harmonics. Typical cepstrum test and measurement applications are bearing and gearbox diagnosis.

Use the modeling VIs to build a linear model for a time series. The Advanced Signal Processing Toolkit includes the following modeling algorithms:

- AR
- MA
- ARMA
- Stochastic state-space

By building the linear model for a time series, you can use the linear model for time-series prediction, machine condition assessment, and other system property studies in a wide range of applications. With the stochastic state-space model, you can estimate such modal parameters as natural frequency, damping, and modal shape for a structure.

Wavelet Analysis

Wavelets are oscillatory and compact signals that have zero-mean and limit width in both the time and frequency domains. In other words, wavelets are compact and local in these domains. Wavelet analysis algorithms represent a signal by wavelets. The wavelet analysis algorithms have the following advantages because of the characteristics of wavelets:

- Ideal for detecting discontinuities, spikes, sharp peaks/valleys, edges, and other transients in signals or images
- Ideal for compressing signals/images because wavelet analysis results in a sparse representation of signals/images
- Ideal for reducing noise or removing trends because wavelet analysis is performed over multiple resolutions

The Advanced Signal Processing Toolkit includes the following wavelet analysis algorithms/tools:

- Graphically Wavelet Design Express VI
- Multiresolution Analysis Express VI (1D and 2D) to perform discrete wavelet transform
- Continuous wavelet transform (CWT)
- Discrete wavelet transform (DWT) and its inverse
- Undecimated wavelet transform and its inverse
- Integer wavelet transform and its inverse
- Wavelet packet
- Arbitrary path wavelet decomposition
- Signal Denoising Express VI
- Signal detrending
- Peak detection
- Edge detection
- Mother wavelet and scaling function

You can use the wavelet analysis VIs in these applications:

- Noise reduction
- Trend removal
- Discontinuities, spikes, peaks/valleys, and edge detection
- Spectral estimation
- Signal/image compression
- Feature extraction

Algorithm Selection

By exploring a signal in the time-frequency plane, you can understand the signal characteristics better and then select proper algorithms for the signal. As Figure 1 shows, you can classify signals into the following categories based on time-frequency characteristics:

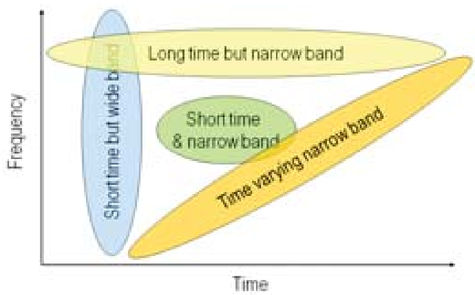


Figure 1. Signal Classification

- Type I – long-time duration but narrow bandwidth, for example, a single-tone signal
- Type II – short-time duration but wide bandwidth, for example, spikes, sharp peaks/valleys, and discontinuous points
- Type III – short-time duration and narrow bandwidth, for example, burst oscillation
- Type IV – time-varying bandwidth, for example, the imbalance bearing generating noise dependent on RPM

You can use different signal processing algorithms for different types of signals based on the signal's characteristics in the time-frequency plane. Table 1 shows the guidelines for selecting proper algorithms.

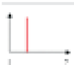
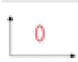
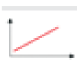
	Signal Type	Frequency Analysis	Order Analysis	Time-Frequency Analysis	Que-frequency Analysis	Wavelet Analysis	Model Based
	I	✔	–	–	–	–	✔
	II	–	–	–	–	✔	✔
	III	–	–	–	–	✔	–
	IV	–	✔	✔	–	–	–
	–[1]	✔	–	–	✔	–	–

Table 1. Guidelines for Algorithm Selection

[1]Signals containing harmonics that do not change over time.

For type I signals, use standard frequency analysis algorithms such as FFT to estimate and analyze the power spectrum of a signal. Use model-based algorithms such as AR spectrum to obtain the high-resolution power spectrum of a signal when the signal has a small number of samples. For type II signals, use wavelet analysis algorithms to detect transients. You also can look at the modeling error of AR modeling to judge the presence of transients. For type III signals, a proper wavelet might match the signal of interest. For type IV signals, you can use time-frequency analysis algorithms to investigate how the frequency components evolve over time, filter the signal in the time-frequency domain, and improve signal-to-noise ratio. If the time-varying signals come from rotational machines and have tacho signals, you can use order analysis algorithms to resample the signal into even-angle samples and analyze the signal in the angle (order) domain. Refer to the NI Sound and Vibration Measurement Suite for more information about order analysis. In addition, you can use cepstrum to detect the presence of harmonics in signals.

Application Areas/Industries

Modern scientific research and engineering often overlap and involve many different signal processing algorithms. The Advanced Signal Processing Toolkit provides fundamental algorithms for time-frequency, time-series, and wavelet analysis. In general, you can use these algorithms in all scientific research, education, and engineering domains. Because NI released the first version of the Advanced Signal Processing Toolkit in the early 1990s, applications in the areas and industries described in the next paragraph extensively incorporate the toolkit.

ATE/Instrumentation

Automated test equipment (ATE) and instruments are widely used to test electronic devices and systems. An ATE application usually involves three steps: data acquisition, signal processing and analysis, and visualization (or report). Signal processing and analysis algorithms are key to ATE, especially when the system under test acquires sound, vibration, or other informative signals. The advanced algorithms in the Advanced Signal Processing Toolkit help you better process the signals and extract useful information from the signals.

Ordering Information

NI LabVIEW Advanced Signal Processing Toolkit 777136-01

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