SIGPRO

Signal Processing Library
API Documentation

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SIGPRO LIBRARY OVERVIEW

This reference manual describes a signal processing library designed to assist in the development of auditory research software. Current functions include random number generators, fft, inverse fft, frequency shaping (filtering), and sample rate conversion. Limited support has been added for loading and saving binary (MAT) files. The current version of the SIGPRO library is 0.22. The most version of the SIGPRO source code and documentation can be downloaded from http://audres.org/rc/sigpro/.

SIGPRO FUNCTION DESCRIPTIONS

sp_bessel

Bessel-style IIR filter design.

(void) **sp_bessel**(float ***b**, float ***a**, int **n**, float ***wn**, int **ft**)

Parameters

b	input (numerator) coefficients
a	output (denominator) coefficients
n	order of filter
wn	cutoff frequency *re* Nyquist frequency
ft	filter type

Return Value

none

Remarks

Filter design is based on a bilinear transformation of the classic analog Bessel (type I) filter. The filter type specifies whether the filter is low-pass (ft=0), high-pass (ft=1), band-pass (ft=2), or band-stop (ft=3). The cutoff frequency is divided by half the sampling rate (*i.e.*, the Nyquist frequency). The number of elements in the input and output coefficient arrays will be the order of the filter plus 1 for low-pass or high-pass filters (ft=0 or ft=1). The number of elements in the input and output coefficient arrays will be twice the order of the filter plus 1 for band-pass or band-stop filters (ft=0 or ft=1). Only one cutoff frequency is needed when the filter type is low-pass or high-pass. Two cutoff frequencies are needed when the filter type is band-pass or band-stop. The input and output coefficient arrays may be used to perform filtering with **sp_rcfft**.

See Also

sp_butter, sp_cheby, sp_filter

sp_butter
Butterworth-style IIR filter design.

(void) **sp_butter**(float ***b**, float ***a**, int **n**, float ***wn**, int **ft**)

Parameters

b	input (numerator) coefficients
a	output (denominator) coefficients
n	order of filter
wn	cutoff frequency *re* Nyquist frequency
ft	filter type

Return Value

none

Remarks

Filter design is based on a bilinear transformation of the classic analog Chebyshev (type I) filter. The filter type specifies whether the filter is low-pass (ft=0), high-pass (ft=1), band-pass (ft=2), or band-stop (ft=3). The cutoff frequency is divided by half the sampling rate (*i.e.*, the Nyquist frequency). The number of elements in the input and output coefficient arrays will be the order of the filter plus 1 for low-pass or high-pass filters (ft=0 or ft=1). The number of elements in the input and output coefficient arrays will be twice the order of the filter plus 1 for band-pass or band-stop filters (ft=2 or ft=3). Only one cutoff frequency is needed when the filter type is low-pass or high-pass. Two cutoff frequencies are needed when the filter type is band-pass or band-stop. The input and output coefficient arrays may be used to perform filtering with **sp_filter**.

See Also

sp_bessel, sp_cheby, sp_filter

sp_cdb

Returns real decibels for a complex input.

(void) **sp_cdb**(float ***x**, float ***db**, int **n**)

Parameters

x	complex[1] input array
db	real output array (dB)
n	output array size

Return Value

none

Remarks

Useful for obtaining spectral magnitude from the complex spectral values returned by **sp_rcfft**. Output array has the same number of elements as the input array, but is half the size because it has no imaginary components.

[1] The old-style complex format is used in which real and imaginary components alternate within a single float array with size equal to twice the number of complex values.

sp_chirp
Generate frequency-sweep waveform.

(void) **sp_chirp**(float *****x**, int **n**)

Parameters

x	output array
n	array size

Return Value

none

Remarks

The waveform generated in the x array is a sine wave with instantaneous frequency that increases linearly with time from the lowest to the highest possible frequency. The maximum amplitude of this frequency-sweep tone is one.

sp_cgd

Returns real group delay for a complex input.

(void) **sp_cgd**(float ***x**, float ***gd**, int **n**, double **df**)

Parameters

x	complex[2] input array
gd	real output array (s)
n	output array size
df	frequency increment (Hz)

Return Value

none

Remarks

Useful for obtaining group delay from the complex spectral values returned by **sp_rcfft**. Output array has the same number of elements as the input array, but is half the size because it has no imaginary components.

[2] The old-style complex format is used in which real and imaginary components alternate within a single float array with size equal to twice the number of complex values.

sp_cheby
Chebyshev-style IIR filter design.

(void) **sp_cheby**(float *__b__, float *__a__, int **n**, float *__wn__, int **ft**, double **rip**)

Parameters

b	input (numerator) coefficients
a	output (denominator) coefficients
n	order of filter
wn	cutoff frequency *re* Nyquist frequency
ft	filter type
rip	pass-band ripple (dB)

Return Value

none

Remarks

Filter design is based on a bilinear transformation of the classic analog Chebyshev (type I) filter. The filter type specifies whether the filter is low-pass (ft=0), high-pass (ft=1), band-pass (ft=2), or band-stop (ft=3). The cutoff frequency is divided by half the sampling rate (*i.e.*, the Nyquist frequency). The number of elements in the input and output coefficient arrays will be the order of the filter plus 1 for low-pass or high-pass filters (ft=0 or ft=1). The number of elements in the input and output coefficient arrays will be twice the order of the filter plus 1 for band-pass or band-stop filters (ft=0 or ft=1). Only one cutoff frequency is needed when the filter type is low-pass or high-pass. Two cutoff frequencies are needed when the filter type is band-pass or band-stop. The input and output coefficient arrays may be used to perform filtering with **sp_rcfft**.

See Also

sp_bessel, sp_butter, sp_filter

sp_cmagsq
Complex magnitude squared.

(void) **sp_cmagsq**(float ***x**, float ***y**, int **n**)

Parameters

x	complex input array
y	complex output array
n	complex array size

Return Value

None

Remarks

The input and output arrays float variables with alternating real and imaginary parts of complex values. The arrays size is the number of real and imaginary pairs in each array. On exit, the real part of the output arrays contains the sum of the squares of the real and imaginary parts of the corresponding complex value in the input array. The imaginary parts of the output array are all set to zero.

sp_convert
Convert sampling rate.

(int) **sp_convert**(float ***x1**, int **n1**, float ***x2**, int **n2**, double **rr**, int **wrap**)

Parameters

x1	input waveform
n1	input size
x2	output waveform
n2	output size
rr	sample rate ratio
wrap	wrap flag (0=no, 1=yes)

Return Value

0	Success
1	Null values passed

Remarks

Uses the waveform in **x1** and sinc-function interpolation to create a waveform in **x2** with **n2** number of samples. Set parameter **rr** to the desired ratio of output sampling rate to input sampling rate or set **rr=0** to select a sampling rate ratio equal to **n2/n1**. The waveform in **x1** is assumed to be zero outside the specified range when **wrap=0**, or assumed to be periodic when **wrap=1**.

sp_copy
Copies an array

(void) **sp_copy**(float ***x**, float ***y**, int **n**)

Parameters

x	input array
y	output array
n	array size

Return Value

none

Remarks

Copies **x** into **y**.

sp_cph

Returns real phase for a complex input.

(void) **sp_cph**(float ***x**, float ***ph**, int **n**)

Parameters

x	complex[3] input array
ph	real output array (cycles)
n	complex array size

Return Value

none

Remarks

Useful for obtaining spectral phase from the complex spectral values returned by **sp_rcfft**. Use **sp_unwrap** to unwrap phase. Output array has the same number of elements as the input array, but is half the size because it has no imaginary components.

[3] The old-style complex format is used in which real and imaginary components alternate within a single float array with size equal to twice the number of complex values.

sp_crfft
Complex to real inverse FFT

(int) **sp_crfft**(float ***x**, int **n**)

Parameters

x	complex[4] input, real output array
n	output size + 2

Return Value

0	success

Remarks

Performs inverse (complex to real) FFT on **x** (in place). If **n** is a power of two, then a fast Fourier transform is used; otherwise the Fourier transform is slow. The input **x** is expected to contain **n/2+1** complex values (i.e., **x[0]=real**, **x[1]=imaginary**, etc.). Returned in **x** are **n** real values. The **x** array size is **n+2**.

[4] The old-style complex format is used in which real and imaginary components alternate within a single float array with size equal to twice the number of complex values.

sp_cvadd
Complex-vector add

(void) **sp_cvadd**(float *__x__, float *__y__, float *__z__, int **n**)

Parameters

x	input array
y	input array
z	output array
n	array size

Return Value

none

Remarks

Adds two complex vectors: **z = x+y**.

The old-style complex format is used in which real and imaginary components alternate within a single float array with size equal to twice the number of complex values.

sp_cvdiv
Complex-vector divide

(int) **sp_cvdiv**(float *__x__, float *__y__, float *__z__, int **n**)

Parameters

x	input array
y	input array
z	output array
n	array size

Return Value

Number of divisions by zero (not performed). Values are returned for all non-zero divisions.

Remarks

Divides two complex vectors: **z = x/y**.

The old-style complex format is used in which real and imaginary components alternate within a single float array with size equal to twice the number of complex values.

sp_cvmul
Complex-vector multiply

(void) **sp_cvmul**(float ***x**, float ***y**, float ***z**, int **n**)

Parameters

x	input array
y	input array
z	output array
n	array size

Return Value

none

Remarks

Multiplies two complex vectors: **z = x*y**.

The old-style complex format is used in which real and imaginary components alternate within a single float array with size equal to twice the number of complex values.

sp_cvsub
Complex-vector subtract

(void) **sp_cvsub**(float ***x**, float ***y**, float ***z**, int **n**)

Parameters

x	input array
y	input array
z	output array
n	array size

Return Value

none

Remarks

Subtracts two complex vectors: **z = x-y**.

The old-style complex format is used in which real and imaginary components alternate within a single float array with size equal to twice the number of complex values.

sp_fft
Complex to complex fft.

(int) **sp_fft**(float *x, int n)

Parameters

x	complex[5] input, complex output array
n	input/output size

Return Value

0	success

Remarks

Performs FFT (in place) on **x**. The input and output arrays are complex, with alternating real and imaginary values. If **n** is a power of two, then a fast Fourier transform is used; otherwise the Fourier transform is slow. The **x** array size is **2n**.

[5] The old-style complex format is used in which real and imaginary components alternate within a single float array with size equal to twice the number of complex values.

sp_fftfilt
FIR filter using FFT-based overlap-add method.

(int) **sp_fftfilt**(float ***b**, int **nb**, float ***x**, int **n**, float ***y**, int **wrap**)

Parameters

b	input-coefficient array
nb	input-coefficient array size
x	input data array
n	input/output data array size
y	output data array
wrap	wrap flag (0=no, 1=yes)

Return Value

0	success

Remarks

Performs FIR filter in place on x using FFTs. The input and output are assumed to be periodic when **wrap=1**.

sp_fftfiltz
FIR filter using FFT-based overlap-add method with history.

(int) **sp_fftfiltz**(float ***b**, int **nb**, float ***x**, int **n**, float ***y**, float ***z**)

Parameters

b	input-coefficient array
nb	input-coefficient array size
x	input data array
n	input/output data array size
y	output data array
z	history data array (size=nb)

Return Value

0	success

Remarks

Performs FIR filter in place on x using FFTs. The history data array contains output data that extends beyond the output data array.

sp_filter
Filter data with recursive (IIR) or non-recursive (FIR) filter.

(int) **sp_filter**(float *__b__, int **nb**, float *__a__, int **na**, float *__x__, float *__y__, int **n**)

Parameters

b	input-coefficient array
nb	input-coefficient array size
a	output-coefficient array
na	output-coefficient array size
x	input data array
y	output data array
n	input/output array size

Return Value

Error code

Remarks

A non-recursive (FIR) filter is specified by setting **a=NULL** and/or **na=0**. Recursive filter coefficients are normalized when **a[0]** is not equal to **1**.

sp_filterz

Filter data with recursive (IIR) or non-recursive (FIR) filter with history.

(int) **sp_filterz**(float ***b**, int **nb**, float ***a**, int **na**, float ***x**, float ***y**, int **n**, float ***z**)

Parameters

b	input-coefficient array
nb	input-coefficient array size
a	output-coefficient array
na	output-coefficient array size
x	input data array
y	output data array
n	input/output data array size
z	history data array (size=nb)

Return Value

Error code

Remarks

A non-recursive (FIR) filter is specified by setting **a=NULL** and/or **na=0**. Recursive filter coefficients are normalized when **a[0]** is not equal to **1**. The history data array contains output data that extends into the input data (on input) or beyond the output data (on output).

sp_firdb

FIR frequency shape filter.

(int) sp_firdb(float *b, int nb, float fs, float *ft, float *at, int nt)

Parameters

b	FIR waveform
nb	FIR size
fs	sampling frequency (Hz)
ft	frequency table (Hz)
at	attenuation table
nt	table size

Return Value

0	Success
1	Table size too small
2	ft order non-monotonic
3	ft range not within 0 and fs/2

Remarks

Returns an impulse response of length n for an FIR filter with the specified frequency response. If **nb** is a power of two, then a fast Fourier transform is used; otherwise the Fourier transform is slow. Array **ft** contains the specific frequencies to shape. Array **at** contains dB attenuation values. The size of both **ft** and **at** arrays is **nt**. Array **ft** must have **0** as its first entry and **fs/2** as its last entry.

sp_fmins

Search variable space to find minimum value of an error function.

(int) sp_fmins(float *v, int n, double (*e)(float *), OPT *o)

Parameters

v	Variable array
n	Array size
e	Error function pointer
o	Options

Return Value

0	Success
1	Too many variables

Remarks

Uses the *simplex* method to find the set of values that minimizes the return value of a specified function. The parameter array must contain initial values on entry, which will be replaced by final values on return. The *error function* accepts a trial set of parameter values. This function returns an error value, such as the sum of squared deviations. The option structure allows some control over iteration details or can be set to NULL. The OPT structure is described in Appendix B. See sp_*fminsearch* for a similar function with an additional argument for passing user-defined parameter data.

sp_fminsearch
Search variable space to find minimum value of an error function.

(int) sp_fminsearch(float *v, int n, double (*e)(float *, void *), OPT *o, void *p)

Arguments

v	Variable array
n	Array size
e	Error function pointer
o	Options
p	Parameter data pointer

Return Value

0	Success
1	Too many variables

Remarks

Uses the *simplex* method to find the set of values that minimizes the return value of a specified function. The parameter array must contain initial values on entry, which will be replaced by final values on return. The *error function* accepts a trial set of parameter values and a pointer to user-defined parameter data. This function returns an error value, such as the sum of squared deviations. The option structure allows some control over iteration details or can be set to NULL. The OPT structure is described in Appendix B. See sp*_fmins* for a similar function without the argument for passing user-defined parameter data.

sp_freqshape
Performs frequency shaping on periodic input waveform.

(int) **sp_freqshape**(float ***f**, float ***x**, float ***y**, int **n**, float ***ft**, float ***at**, int **nt**)

Arguments

f	fft frequencies (Hz)
x	input waveform
y	output waveform
n	waveform size
ft	frequency table (Hz)
at	attenuation table (dB)
nt	table size

Return Value

0	Success
1	Table size too small
2	**ft** order non-monotonic
3	**f** outside range of **ft**

Remarks

Performs frequency shaping on **x** and returns the modified waveform in **y**. The size of both **x** and **y** arrays is **n**. If that size is a power of two, then the filtering, which uses an FFT, will be much faster. The input and output arrays are assumed to be periodic. Array **f** contains the frequencies of the spectrum of **x** and its size is **n/2+1**. Array **ft** contains the specific frequencies to shape. Array **at** contains dB attenuation values. The size of both **ft** and **at** arrays is **nt**. The range of **ft** must span **f**. The **sp_freqshape** function has been deprecated and replaced by the **sp_frqshp** function.

See Also

sp_frqshp

sp_freqz
IIR filter transfer function.

(void) **sp_freqz**(float ***b**, int **n**b, float ***a**, int **na**, float ***f**, float ***H**, int **nf, double fs**)

Arguments

b	input (numerator) coefficients
nb	number of input coefficients
a	output (denominator) coefficients
na	number of output coefficients
f	array of frequencies (Hz)
H	complex[6] transfer function H=b(z)/a(z)
nf	number of frequencies
fs	sampling rate (Hz)

Return Value

none

Remarks

A transfer function for the IIR filter defined by **b** and **a** is returned in **H** at each frequency listed in **f**. The frequencies in **f** are in the same units as the sampling rate **fs**.

See Also

sp_transfer

[6] The old-style complex format is used in which real and imaginary components alternate within a single float array with size equal to twice the number of complex values.

sp_frqshp
Performs frequency shaping on arbitrary input waveform.

(int) **sp_frqshp**(float ***x**, float ***y**, int **n**, double **fs**, float ***fr**, float ***at**, int **nt**, int **wrap**)

Arguments

x	input waveform
y	output waveform
n	waveform size
nf	FIR filter size
fs	sampling frequency (Hz)
fr	frequency table (Hz)
at	attenuation table
nt	table size
wrap	wrap flag (0=no, 1=yes)

Return Value

0	Success
1	Table size too small
2	ft order non-monotonic
3	ft range outside 0 and fs/2

Remarks

Performs frequency shaping on **x** and returns the modified waveform in **y**. The size of both **x** and **y** arrays is **n**. Array **ft** contains the specific frequencies to shape. Array **at** contains dB attenuation values. The size of both **ft** and **at** arrays is **nt**. Array **ft** must have **0** as its first entry and **fs/2** as its last entry. The waveform and FIR sizes (**n** and **nf**) are not required to be a power of two. The FFT size will be the power of 2 that is greater or equal to **nf**. The **sp_frqshp** function replaces the **sp_freqshape** function.

sp_ifft
Complex to complex inverse fft.

(int) **sp_ifft**(float ***x**, int **n**)

Arguments

x	complex[7] input, complex output array
n	input/output size

Return Value

Error code

Remarks

Performs and inverse FFT on **x** (in place). The input and output arrays are complex, with alternating real and imaginary values. If **n** is a power of two, then a fast Fourier transform is used; otherwise the Fourier transform is slow. The **x** array size is **2n**.

[7] The old-style complex format is used in which real and imaginary components alternate within a single float array with size equal to twice the number of complex values.

sp_interp
Interpolates tabled values.

(int) **sp_interp**(float ***x1**, float ***y1**, int n1, float ***x2**, float ***y2**, int **n2**);

Arguments

x1	table x
y1	table y
n1	table size
x2	interpolate x
y2	interpolate y
n2	interpolate size

Return Value

0	Success
1	Table size too small
2	Table nonmontonic

Remarks

Performs linear interpolation. The values in **x1** and **y1** are used to create a new set of values in **x2** and **y2** with **n2** number of points.

sp_linspace
Generates linearly spaced values

(void) **sp_linspace**(float *__x__, int **n**, double **a**, double **b**)

Arguments

x	output array
n	array size
a	first value
b	last value

Return Value

none

Remarks

Returns n values linearly spaced between **a** and **b** in **x**.

sp_mat_append
Appends variables to an existing MAT-format file.

(int) **sp_mat_append**(char ***fn**, VAR ***vl**)

Arguments

fn	file name
vl	variable list

Return Value

error code, which is zero for no errors

Remarks

Elements of the variable list are of type VAR, which is described in Appendix A.

See also

sp_mat_whos, *sp_mat_load*

sp_mat_fetch
Reads one variables from a MAT-format file.

(VAR *) **sp_mat_fetch**(char ***fn**, char ***vn, short *irc, short *nrc**)

Arguments

fn	file name
vn	variable name
irc	initial row and column
nrc	number of rows and columns

Return Value

list of variables

Remarks

Elements of the variable list are of type VAR, which is described in Appendix A. The parameters irc and nrc specify a subset of the array. They each point to short arrays with two elements containing row and column values or may be set to NULL. Setting irc to NULL is equivalent to setting row and column to zero. Setting nrc to NULL is equivalent to setting rows and columns to the dimensions of the variable stored in the file.

See also

sp_mat_whos, sp_mat_save

sp_mat_load
Reads all variables from a MAT-format file.

(VAR *) **sp_mat_load**(char ***fn**)

Arguments

fn	file name

Return Value

list of variables

Remarks

Elements of the variable list are of type VAR, which is described in Appendix A.

See also

sp_mat_whos, *sp_mat_save*

sp_mat_save
Writes variables to a MAT-format file.

(int) **sp_mat_save**(char ***fn**, VAR ***vl**)

Arguments

fn	file name
vl	variable list

Return Value

error code, which is zero for no errors

Remarks

Elements of the variable list are of type VAR, which is described in Appendix A.

See also

sp_mat_whos, *sp_mat_load*

sp_mat_size
Counts variables in a MAT-format file.

(int) **sp_mat_size**(char ***fn**)

Arguments

fn file name

Return Value

number of variables

Remarks

Elements of the variable list are of type VAR, which is described in Appendix A.

See also

sp_mat_whos, sp_mat_save

sp_mat_version
Returns MAT file version number.

(int) **sp_mat_version**(char ***fn**)

Arguments

fn file name

Return Value

version number

Remarks

Version number is either 4 or 5 when the file is recognized as a valid MAT file. The version number is 0 when the file is not recognized as a valid MAT file.

See also

sp_mat_ size

sp_mat_whos
Reads all variable names in a MAT-format file.

(VAR *) **sp_mat_whos**(char ***fn**)

Arguments

fn file name

Return Value

list of variable names. This is the same as the variable list returned by *sp_mat_load*, except without any data.

Remarks

Elements of the variable list are of type VAR, which is described in Appendix A.

See also

sp_mat_load, sp_mat_save

sp_nxtpow2
Returns the power of 2 that is greater than or equal to the input.

(int) **sp_nxtpow2**(int **n**)

Arguments

n	array size

Return Value

none

Remarks

The returned value is a power of two that is greater than or equal to the input.

sp_rand
Generates uniform random values.

(void) sp_rand(float ***x**, int **n**)

Arguments

x	output array
n	array size

Return Value

none

Remarks

Generates **n** uniform random values between **0** and **1**. Call **sp_randseed** to specify the generator seed before calling **sp_rand**.

sp_randflat
Generates random values with a flat spectrum

(int) **sp_randflat**(float *__x__, int **n**)

Arguments

x	output array
n	array size

Return Value

0	Success
1	N is not a power of 2

Remarks

Generates **n** random numbers with a flat spectrum. Call **sp_randseed** to specify the generator seed before calling **sp_randflat**.

sp_randn

Generates normal random values.

(void) **sp_randn**(float *__x__, int **n**)

Arguments

x	output array
n	array size

Return Value

none

Remarks

Uses the ziggurat method to generate **n** normally-distributed random values with mean **0** and standard deviation **1**. Call **sp_randseed** to specify the generator seed before calling **sp_randn**.

sp_randseed
Seeds the random number generator

(void) **sp_randseed**(unsigned long **s**)

Arguments

s	seed

Return Value

none

Remarks

Seeds the random number generator for sp_rand, sp_randflat, and sp_randn.

sp_rcfft
Performs in place real to complex fft.

(int) **sp_rcfft**(float ***x**, int **n**)

Arguments

x	real input, complex[8] output array
n	input size + 2

Return Value

0	success

Remarks

Performs (real to complex) FFT on **x** (in place). If **n** is a power of two, then a fast Fourier transform is used; otherwise the Fourier transform is slow. The input **x** contains **n** real values. Returned are **n/2+1** complex values (i.e. **x[0]=real**, **x[1]=imaginary**, etc). The **x** array size is **n+2**.

[8] The old-style complex format is used in which real and imaginary components alternate within a single float array with size equal to twice the number of complex values.

sp_sadd
Scalar add

(void) **sp_sadd**(float ***x**, float ***y**, int **n**, double **a**)

Arguments

x	input array
y	output array
n	array size
a	scalar

Return Value

none

Remarks

Performs a scalar add: **y = x+a**.

sp_sma
Scalar multiply and add

(void) **sp_sma**(float ***x**, float ***y**, int **n**, double **b**, double **a**)

Arguments

x	input array
y	output array
n	array size
b	scalar
a	scalar

Return Value

none

Remarks

Performs scalar multiplication and addition: **y = x*b+a**.

sp_smul
Scalar multiply

(void) **sp_smul**(float ***x**, float ***y**, int **n**, double **b**)

Arguments

x	input array
y	output array
n	array size
b	scalar

Return Value

none

Remarks

Performs scalar multiplication: **y = x*b**.

sp_tic
Start a stopwatch timer

(double) **sp_tic**()

Arguments

none

Return Value

Returns current time of day in seconds.

Remarks

Save current time for subsequent call to *sp_toc*.

sp_toc
Read a stopwatch timer

(double) **sp_toc**()

Arguments
none

Return Value
Returns elapsed time in seconds.

Remarks
Elapsed time since prior call to *sp_tic*.

sp_transfer
Calculate transfer function given stimulus and response waveforms.

(int) **sp_transfer**(float ***x**, float ***y**, int **n**, float ***H**)

Arguments

x	stimulus waveform
y	response waveform
n	input array size
H	complex[9] transfer function H=fft(y)/fft(x)

Return Value

Error code is zero when no error occurs.

Remarks

Computation is much faster when the input array size is a power of 2. The transfer function is complex valued, so real and imaginary components alternate. The transfer function will have nf=(n/2+1) complex elements. The size of the transfer-function array should be equal to the input array size plus two.

See Also

sp_freqz

---

[9] The old-style complex format is used in which real and imaginary components alternate within a single float array with size equal to twice the number of complex values.

sp_unwrap
Unwrap phase.

(void) **sp_unwrap**(float ***x**, float ***y**, int **n**)

Arguments

x	input phase array (cycles)
y	output phase array (cycles)
n	array size

Return Value

none

Remarks

Unwraps phase assuming that one cycle equals **1**. The output array may be identical to the input array.

sp_vadd
Vector addition.

(void) **sp_vadd**(float ***x**, float ***y**, float ***z**, int **n**)

Arguments

x	input array
y	input array
z	output array
n	array size

Return Value

none

Remarks

Adds two vectors: **z = x+y**.

sp_var_add
Adds a new variable to a list of variables.

(void) **sp_var_add**(VAR *__vl__, char *__name__, void *__data__, int **rows**, int **cols**, char *__frmt__)

Arguments

vl	pointer to a list of variables
name	variable name
data	pointer to data array to be assigned to this variable
rows	number of rows
cols	number of column
frmt	string of characters specifying data type

Return Value

none.

See also

sp_var_set, *sp_var_ allocate*

sp_var_alloc
Allocates memory for a list of variables.

(VAR *) **sp_var_alloc**(int **nvar**)

Arguments

nvar	number of variables

Return Value

list of (unspecified) variables.

Remarks

Elements of the variable list are of type VAR, which is described in Appendix A.

See also

sp_var_set, sp_mat_save

sp_var_clear
Frees all memory for a list of variables.

(void) **sp_var_clear**(int **nvar**)

Arguments

nvar number of variables

Return Value

none.

Remarks

Elements of the variable list are of type VAR, which is described in Appendix A.

See also

sp_var_set, sp_var_clear

sp_var_clear_all
Frees all memory for all lists of variables.

(void) **sp_var_clear_all**(void)

Arguments

none.

Return Value

none.

Remarks

Elements of the variable list are of type VAR, which is described in Appendix A.

See also

sp_var_set, sp_var_clear

sp_var_copy
Copies a list of variables.

(VAR *) **sp_var_copy**(VAR ***vl**)

Arguments

vl	list of variables

Return Value

list of variables.

Remarks

Elements of the variable list are of type VAR, which is described in Appendix A.

See also

sp_var_set, sp_var_ allocate

sp_var_dattyp

Adds a new variable to a list of variables.

(char *) **sp_var_dattyp**(int **dt**)

Arguments

dt	numeric data type

Return Value

Returns the string descriptor of a numeric data type such as “I2” or “F4”.

See also

sp_var_add

sp_var_find
Find variable in list by name.

(int) **sp_var_find**(VAR ***vl**, char ***vn**)

Arguments

vl	list of variables
vn	variable name

Return Value

Variable index or -1 if not found.

Remarks

Searches variable list for specified name.

See also

sp_mat_find

sp_var_float
Converts data type of all variables in a list to single-precision (32-bit) floating point.

(void) **sp_var_float**(VAR ***vl**)

Arguments

vl	list of variables

Return Value

none.

Remarks

Elements of the variable list are of type VAR, which is described in Appendix A.

See also

sp_var_set, sp_var_ allocate

sp_var_f4
Returns one single-precision float value from variable list by name.

(float) **sp_var_f4**(VAR ***vl**, char ***vn**)

Arguments

vl	list of variables
vn	variable name

Return Value

First value in variable array.

Remarks

Searches variable list for specified name.

See also

sp_var_f8, *sp_var_i2*, *sp_var_i4*

sp_var_f8
Returns one double-precision float value from variable list by name.

(double) **sp_var_f8**(VAR ***vl**, char ***vn**)

Arguments

vl	list of variables
vn	variable name

Return Value

First value in variable array.

Remarks

Searches variable list for specified name.

See also

sp_var_f4, *sp_var_i2*, *sp_var_i4*

sp_var_i2
Returns one short-integer value from variable list by name.

(short) **sp_var_i2**(VAR ***vl**, char ***vn**)

Arguments

vl	list of variables
vn	variable name

Return Value

First value in variable array.

Remarks

Searches variable list for specified name.

See also

sp_var_f4, sp_var_f8, sp_var_i4

sp_var_i4
Returns one long-integer value from variable list by name.

(long) **sp_var_i4**(VAR ***vl**, char ***vn**)

Arguments

vl	list of variables
vn	variable name

Return Value
First value in variable array.

Remarks
Searches variable list for specified name.

See also
sp_var_f4, sp_var_f8, sp_var_i2

sp_var_set
Specifies variable properties in a list of variables.

(void) **sp_var_set**(VAR ***vl**, char ***name**, void ***data**, int **rows**, int **cols**, char ***frmt**)

Arguments

vl	pointer to a variable in a list of variables
name	variable name
data	pointer to data array to be assigned to this variable
rows	number of rows
cols	number of column
frmt	string of characters specifying data type

Return Value

none.

Remarks

Elements of the variable list are of type VAR, which is described in Appendix A. The data format string should begin with I, U, F, or T to specify integer, unsigned integer, floating-point, or text, respectively. When the first letter is I or U, it should be followed by 1, 2, or 4 to specify the number of bytes of integer precision. When the first letter is F, it should be followed by 4 or 8 to specify the number of bytes of floating-point precision. The number in the format string may also be followed by C to specify complex[10] data.

As a special case, when frmt=f4str and data contains a string, then the rows and cols arguments are ignored and the string is stored as an array with frmt=f4.

See also

sp_var_add, *sp_var_ allocate*

[10] The old-style complex format is used in which real and imaginary components alternate within a single float array with size equal to twice the number of complex values.

sp_var_size
Count variables in a list of variables.

(void) **sp_var_size**(VAR ***vl**)

Arguments

vl pointer to a variable in a list of variables

Return Value

number of variables.

Remarks

Elements of the variable list are of type VAR, which is described in Appendix A.

See also

sp_var_set, sp_var_ allocate

sp_var_idx
Finds an empty variable in a list of variables and returns its index.

(void) **sp_var_idx**(VAR ***vl**)

Arguments

vl pointer to a variable in a list of variables

Return Value

Index to an empty variable or -1 when list is full.

Remarks

Used by *sp_var_add*.

See also

sp_var_set, *sp_var_add*

sp_version
Returns SigPro version string.

(char *) **sp_version**()

Arguments
none

Return Value
version string

Remarks
For example, "SigPro version 0.05, 13-Dec-05".

sp_vdot

Returns vector dot product.

(double) **sp_vdot**(float ***x**, float ***y**, int **n**)

Arguments

x	input array
y	input array
n	array size

Return Value

Vector dot product

Remarks

Computes the dot product of vectors **x** and **y**.

sp_vdiv
Vector divide

(int) **sp_vdiv**(float ***x**, float ***y**, float ***z**, int **n**)

Arguments

x	input array
y	input array
z	output array
n	array size

Return Value

Number of divisions by zero (not performed). Values are returned for all non-zero divisions.

Remarks

Divides two vectors: **z = x/y**.

sp_vmax
Vector maximum

(int) **sp_vmax**(float ***x**, int **n**)

Arguments

x	input array
n	array size

Return Value

Index of first element with maximum value

sp_vmin
Vector minimum

(int) **sp_vmin**(float *__x__, int **n**)

Arguments

x	input array
n	array size

Return Value

Index of first element with minimum value

sp_vmul
Vector multiply

(void) **sp_vmul**(float ***x**, float ***y**, float ***z**, int **n**)

Arguments

x	input array
y	input array
z	output array
n	array size

Return Value

none

Remarks

Multiplies each element of two vectors: **z = x*y**.

sp_vsub
Vector subtract

(void) **sp_vsub**(float ***x**, float ***y**, float ***z**, int **n**)

Arguments

x	input array
y	input array
z	output array
n	array size

Return Value

none

Remarks

Subtracts two vectors: **z = x-y**.

sp_wav_info
Read waveform information from WAV file.

(VAR *) **sp_wav_info**(char ***fn**, float ***fs**)

Arguments

fn	file name
fs	sampling rate (samples/sec)

Return Value

Variable containing waveform information, but not the waveform.

Remarks

The number of samples in the waveform is the number of rows in the VAR structure. The number of channels in the waveform is the number of cols in the VAR structure.

See also

sp_wav_read

sp_wav_read
Read waveform from WAV file.

(VAR *) **sp_wav_read**(char ***fn**, int ***ifr**, int ***nfr**, float ***fs**)

Arguments

fn	file name
ifr	pointer to initial frame
nfr	pointer to number of frames
fs	sampling rate (samples/sec)

Return Value

Variable containing waveform, possibly with multiple channels.

Remarks

The number of samples in the waveform is the number of rows in the VAR structure. The number of channels in the waveform is the number of cols in the VAR structure. The waveform data type is float. Partial reads are possible by specifying the initial frame and number of frames. A frame includes all columns of a single row and corresponds with all channels for a single sample time. When the ifr is NULL the first frame is the initial frame. When the nfr is NULL all samples are read from the initial frame to the end of the file.

See also

sp_wav_info

sp_window
Standard window

(int) **sp_window**(float ***y**, int **n**, int **wt**)

Arguments

y	output array
n	array size
wt	window type

Return Value

0	Success
1	invalid window type

Remarks

The window types are 0=rectangular (ones), 1=triangular (Bartlet), 2=Hanning, 3=Hamming, 4=Blackman, 5=Nuttall.

sp_zero
Zeros an array

(void) **sp_zero**(float ***y**, int **n**)

Arguments

y	output array
n	array size

Return Value

none

Remarks

Sets all values in array **y** to 0.

Appendix A. MAT and VAR functions

The functions that load variables from MAT files and save variables to MAT files make use of variable *lists* that are implemented as VAR arrays. The VAR struct is defined in sigpro.h as:

```
struct {
      char *name;
      void *data;
      long rows, cols;
      char dtyp, cmpx, text, last;
}
```

An empty VAR list is created by calling *sp_var_alloc*. The last element in a variable list is indicated by setting the `last=1`. Variable properties may be specified by calling *sp_var_set*. Memory allocated to a single variable list may be freed by calling *sp_var_clear*. Memory allocated to all variable lists may be freed by calling *sp_var_clear_all*. A variable list may be copied by calling *sp_var_copy*. All data in a variable list may be converted to single-precision floating point by calling *sp_var_float*. The *sp_var_size* function counts the number of variables in a variable list.

Four function support MAT files. The *sp_mat_save* function creates version 4 MAT files. The *sp_mat_load* function reads either version 4 or version 5 MAT files. The *sp_mat_whos* function is similar to the *sp_mat_load* function, except that the data is omitted from the variable list. This is useful when only the variable properties are of interest. The *sp_mat_size* function simply counts the number of variables in a MAT file.

The data type for `rows` and `cols` was changed from short to long in version 0.22.

Appendix B. OPT structure

The OPT structure specifies options that allow control over the iteration performed by the *sp_fmins* function. The OPT struct is defined in sigpro.h.

```
struct {
  float icons, ifrac;
  float tolfun, tolx;
  int display, funchk;
  int maxeval, maxiter, miniter;
  int (*escape)(void);
  void (*report)(float *);
}
```

These variables are described below and default values are given in brackets.

icons – Constant used to offset zeros in the initial parameter list when creating a starting simplex. [0.00025]
ifrac – Fraction to offset non-zero values in the initial parameter list when creating a starting simplex. [0.05]
ffrac – Minimum change required in successive parameter with the largest fractional change to allow iteration to continue. [0.0001]
tolfun – Minimum change required in successive error function values to allow iteration to continue. [Not implemented.]
tolx – Minimum change required in successive parameter-list norms to allow iteration to continue. [Not implemented.]
display - [Not implemented.]
funchk - [Not implemented.]
maxeval - [Not implemented.]
maxiter – Maximum number of iterations. [1000]
miniter – Minimum number of iterations. [Number of parameters.]
escape – Callback function terminates iteration when it returns true. [Null]
report – Callback function allows intermediate parameter values to be printed. [Null]

Appendix C. Test Programs

Several programs are included in the source code distribution that test some of the features of the SIGPRO library.

- tst_afd – Test analog filter design.
- tst_bbf – Test Butterworth band-pass filter design.
- tst_fft – Test real & complex[11] FFT and inverse FFT.
- tst_mat – Test MAT file save & load.
- tst_min – Test fmins minimization function.
- tst_shp – Test frequency-shaping functions.
- tst_src – Test sampling-rate conversion.
- tst_wav – Test WAV file read & write.
- tst_xfr – Test transfer-function computation.

[11] The old-style complex format is used in which real and imaginary components alternate within a single float array with size equal to twice the number of complex values.