
Subject: Smoothing Data with optimal wiener filter
Posted by [schaa](#) on Mon, 24 May 2004 16:31:02 GMT
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Hi folks,

i have written a program, which smoothes noisy data with a wiener filter. Return values of the program are the smoothed dataset and the first and second derivatives.

However, the smoothing works satisfying, but the derivatives are going *very* wrong and i could use some suggestions here.

You find the code below.

Any suggestions would be appreciate very much!

-Ralf

P.S:

The program has not an elaborated description as it should have, but wo is interested: the program is based on the paper by:

E.L Kosarev and E. Pantos, J. Phys. E: Vol. 16, 1983

'Optimal Smoothing of noisy data by FFT'

downloadable from <http://kapitza.ras.ru/people/kosarev/1983.pdf>

A Fortran-code is in Int. J. Biomed. Comput. 37 (1994) 57-76 by F. Gazzani

'Comparative assessment of some algorithms for differentiating noisy biomechanical data'

Some basics of the topic found in 'Anderssen, Bloomfield' in 'Numerische Mathematik' (not german but in english), Vol. 22, pp. 157-182, 1974

'Numerical Differentiation procedures for non-exact data'

The program:

```
=====
=====
```

(Derivatives are calculated at line 181)

PRO test_smooth_fft

```
;;-----
;;
;; Create some simple Test-Timeseries
;;-----
```

N = 100 ; Number of Samples

T = 1.D ; Period

```

Delt = T / Double(N) ; Sample interval
Pi2 = (2.*!DPI) ; 2 x Pi
OMEGA = Pi2 / (Float(N)*Delt) ; Angular Sample frequency

```

```

; Ordinate
Y = DblArr(N)
FOR t = 0, N-1 DO BEGIN
  Y[t] = ALOG(t+1) + SIN(t/Pi2)*COS(t/Pi2)
ENDFOR

```

```

; Abscissa
X = FindGen(N) * Delt

```

```

; Add noise:
Dat_O = Y
Dat = Y + RANDOMN(789421, n)*0.3D

```

```

;;-----
;; Center and Baselinefit of the data
;;-----
Dat_m = Dat - Mean(Dat)

Dat_b = FltArr(N)
SLOPE = (Dat_m[N-1]-Dat_m[0])/(N-2)
FOR j=0, N-1 DO BEGIN
  Dat_b[j] = Dat_m[j] - Dat_m[0] - SLOPE * (j)
ENDFOR

```

```

;;-----
;; Compute fft- / power- spectrum
;;-----
; Fourier
Dat_F = FFT(Dat_b) ;HANNING(N, ALPHA=0.56)*
; Power
Dat_P = ABS(Dat_F)^2

```

```

; Frequency for abscissa axis
; F = [0.0, 1.0/(N*delt), ... , 1.0/(2.0*delt)]:
F = FINDGEN(N/2+1) / (N*delt)

```

```

;;-----
;; Noise spectrum from 'half' to 'full'
;; Mind: half means N/4, full means N/2
;;-----

```

```

Sigma = Total(Dat_P[(N-1)/4:(N-1)/2])
; The noise is assumed to be the second half of the periodogram
Noise = Sigma / ((N-1)/2 - (N-1)/4)

```

```

;;-----
;; Get Filtercoeff. according to Kosarev/Pantos
;; Find the J0, start search at i=1 (i=0 is the mean)
;;-----

```

```

J0 = 2
FOR i=1, N/4 DO BEGIN
  Sigma0 = Dat_P[i]
  Sigma1 = Dat_P[i+1]
  Sigma2 = Dat_P[i+2]
  Sigma3 = Dat_P[i+3]

  IF( Sigma0 LT Noise AND $
    (Sigma1 LT Noise OR $
      Sigma2 LT Noise OR $
        Sigma3 LT Noise)) $
  THEN BEGIN
    J0 = i
    BREAK
  ENDIF
ENDFOR

```

```

;;-----
;; Compute straight line extrapolation to log(Dat_P)
;;-----

```

```

XY = 0.
XX = 0.
S = 0.
FOR i =1, J0 DO BEGIN
  XY = XY + i * ALOG(Dat_P[i])
  XX = XX + i * i
  S = S + ALOG(Dat_P[i])
ENDFOR

```

```

; Find parameters A1, B1
XM = (2. + J0) / 2.
YM = S / Float(J0)
A1 = (XY - Float(J0)*XM*YM) / (XX-Float(J0)*XM*XM)
B1 = YM - A1 * XM

```

```

;;-----
;; compute J1, the frequency for which straight
;; line extrapolation drops 20dB below noise

```

```

;;-----
J1 = J0
FOR i = J0, (N-1)/2 DO BEGIN
vgl = EXP(A1+Float(i)+B1)/NOISE
IF (vgl LT 0.01) THEN BEGIN
  J1 = i
  BREAK
ENDIF
ENDFOR

```

```

;;-----
;; Compute the Kosarev-Pantos filter windows
;; Frequency-ranges:
;; 0 -- J0 | J0+1 -- J1 | J1+1 -- N2
;;-----
LOPT = DblArr((N-1)/2 + 1)
FOR i = 0, J0 DO BEGIN
  LOPT[i] = Dat_P[i] / (Dat_P[i] + NOISE)
ENDFOR
FOR i = J0, J1 DO BEGIN
  LOPT[i] = EXP(A1*Float(i)+B1) / (EXP(A1*Float(i)+B1) + NOISE)
ENDFOR
FOR i = J1+1, (N-1)/2 DO BEGIN
  LOPT[i] = 0.
ENDFOR

```

```

;;-----
;; Denoise the Spectrum with the filter
;; Calculate the first and second derivative (i.e. multplie with iW)
;;-----
Smoothed_Data = FltArr(N)
First_Diff = FltArr(N)
Secnd_Diff = FltArr(N)
Fltr_Spectrum = DcomplexArr(N)

; first Loop gives differentiation
FOR diff = 0, 2 DO BEGIN

  FOR j= 1, (N-1)/2 DO BEGIN
    ; make the filter complex
    FltrCoef = Complex(LOPT[j],0.)
    ; differentitation in frequency domain

    iW = Float(j)*OMEGA
    iW = Complex(0., iW)^diff

```

```

; multiply spectrum with filter coefficient
Fltr_Spectrum[j] = Dat_F[j] * FltrCoef * iW
; copy first half of modified spectrum to last half
Fltr_Spectrum[N-j] = Conj(Fltr_Spectrum[j])
ENDFOR

; Fltr_Spectrum[0] is the mean (?),
; which is not considered above
Fltr_Spectrum[0] = Dat_F[0]

; The derivatives of Fltr_Spectrum[0] are 0
IF(diff GT 0) THEN Fltr_Spectrum[0] = Complex(0.,0.)

; Inversal fourier transform back in time domain
Dat_T = FFT(Fltr_Spectrum,/Inverse)
Dat_T[N-1] = Complex(Float(Dat_T[0]), Imaginary(Dat_T[N-1]))

IF(diff EQ 0) THEN BEGIN
; This ist the smoothed time series (baseline added)
FOR j = 0, N-1 DO BEGIN
    Smoothed_Data[j] = Float(Dat_T[j]) + Dat[0] + SLOPE * Float(j)
ENDFOR
ENDIF

IF(diff EQ 1) THEN BEGIN
    R4 = SLOPE / Delt
; The first derivative
FOR j = 0, N-1 DO BEGIN
    First_Diff[j] = Float(Dat_T[j]) + R4
ENDFOR
ENDIF

IF(diff EQ 2) THEN BEGIN
; The second derivative
FOR j = 0, N-1 DO BEGIN
    Secnd_Diff[j] = Float(Dat_T[j])
ENDFOR
ENDIF

ENDFOR

!P.MULTI=0
Plot , X, Dat,Psym=4,SymSize=.5
Oplot, X, Y, LineStyle=4
Oplot, X, Smoothed_Data,LineStyle=0

;OPlot,X,First_Diff,,psym=1

```

```
;savgolFilter = SAVGOL(16, 16, 1, 4)
;OPLOT, X, CONVOL(Y, savgolFilter, /EDGE_TRUNCATE),thick=2
```

```
;;-----
;; Create log-log plot of power spectrum:
;;-----
;PLOT, F, ABS(Dat_F(0:N/2))^2, $
; YTITLE='Power Spectrum of u(k)', /YLOG, $
; XTITLE='Frequency in cycles / second', /XLOG, $
; X RANGE=[1.0,1.0/(2.0*delt)], $
; XSTYLE=1,LINESTYLE=1
```

END
