
Subject: Final Solution of Convolution with Radius dependency

Posted by [bente](#) on Wed, 07 Nov 2001 15:41:33 GMT

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Hi, I just want to present my final solution of the Convolution ;-)
I takes only 50seconds on a 128x128x64 array but round about 10minutes
on a 256x256x128 array.

You can determine if you want no convolution, "normal", or with
r-dependency for each dimension (only with 3D-arrays, had no time to
care about 1 or 2 dimensions ;-)

Wrote it for Gaussian Kernel, but i build the kernel in sub-function
so it sshould be easy to replace it with any other kernel (in the case
that someone should need such stuff, too.

And I don't understand, why the time is so much larger than with the
small array. I found out that it already takes ages to copy the array
in a bit larger array (so i have space at the edges for the size of
the kernel).

So have fun, if someone needs it, or answer if someone has a faster
way ;-)

Kay

```
-----  
;------3Dimensional Convolution with Dependency Of The  
Radius-----  
;-----Kay Bente-----  
;------  
  
;------  
;------Functions Needed-----  
;------
```

FUNCTION Kernel_Size, scale, fac, fw

;Determines the Size of The Kernel from FWHM and a Faktor and the
Scaling of the Dataset (PIXEL <-> mm)

;e.g. scale = [0.9,0.9,1.25]

; FWHM = 6mm

; fac = 3 (Kernel should be 3times larger then the FWHM)

;Kernel_Size= [21,21,15]

; written by Kay Bente

; 11.9.01

```
s=Ceil(fac*fw/scale)
```

```
;Round Up to next largest Odd integer
```

```
s=s+1-(s MOD 2)
```

```
Return, s
```

```
END
```

```
FUNCTION Gauss, s, sig, scale=scale, fwhm=fwhm
```

```
;Create 3D Gaussian
```

```
;Kay Bente, Wuppertal: 06.09.01 - 11.09.01
```

```
;s -> [nx,ny,nz]
```

```
;sigma -> Sigma for Gauss
```

```
;scale -> [sx,sy,sz] for example for MRI images e.g. : [0.9,0.9,1.25]
```

```
;fwhm=1 -> Caluculate with FWHM instead of sigma,
```

```
FWHM=2*sigma*Sqrt(2*ALog(2)) => sigma~FWHM/2.35
```

```
;      sigma input in FWHM
```

```
;Determine Dimensions
```

```
ss=Size(s, /Dimensions)
```

```
CASE ss(0) OF
```

```
    0 : GOTO, label_1D
```

```
    1 : GOTO, label_1D
```

```
    2 : GOTO, label_2D
```

```
    3 : GOTO, label_3D
```

```
ELSE : BEGIN
```

```
    Print, 'Wrong Dimensions!'
```

```
    Print, 'Size(s, /Dimensions) Has To Be Less Or Equal
```

```
3'
```

```
    Print, 'You Entered : ',s
```

```
    Print, String('That has ',StrTrim(String(ss),1), '
```

```
Dimensions!')
```

```
    Print, "'0" Returned!'
```

```
    Return, 0
```

```
    GOTO, label_END
```

```
ENDELSE
```

```
ENDCASE
```

```
;1D
```

```
label_1D:
```

```
;Check Keywords
```

```
IF Keyword_Set(scale) EQ 0 THEN scale = [1]
```

```
IF Keyword_Set(fwhm) THEN sigma = sig/2.35 ELSE sigma = sig
```

```

;Create Indizes
arr = (FindGen(s(0)) - s(0)/2)*scale(0)
;Create Gaussian on Indizes
arr2 = Exp(-(Temporary(arr))^2/(2.*sigma^2))/(Sqrt(2.*!PI)*sigma)
Return,arr2
GOTO, label_END

;2D Adapted from 3D
label_2D:

;Check Keywords
IF Keyword_Set(scale) EQ 0 THEN scale = [1,1]
IF Keyword_Set(fwhm) THEN sigma = sig/2.35 ELSE sigma = sig

;Faktor 1 for odd size
f=[s(0) mod 2, s(1) mod 2]

mid=[s(0)/2 + f(0),s(1)/2 + f(1)]
arr=FltArr(mid(0),mid(1))

fak=2.*sigma^2
fak2=2.*!pi*sigma^2

;Create 1/4 Circle
FOR i=0,mid(0)-1 DO BEGIN
  FOR j=0,mid(1)-1 DO BEGIN
    arr(i,j) = Exp(-((i*scale(0))^2+(j*scale(1))^2)/fak)/fak2
  ENDFOR
ENDFOR

arr2=FltArr(s(0),s(1))

;Copy & Mirror To Fill The Rest Of Circle
arr2(mid(0)-f(0):s(0)-1,mid(1)-f(1):s(1)-1)=arr
arr2(mid(0)-f(0):s(0)-1,0:mid(1)-1)=Reverse(arr,2)
arr2(0:mid(0)-1,0:s(1)-1)=Reverse(arr2(mid(0)-f(0):s(0)-1,0: s(1)-1),1)

Return, arr2
GOTO, label_END

;3D
label_3D:

;Check Keywords
IF Keyword_Set(scale) EQ 0 THEN scale = [1,1,1]
IF Keyword_Set(fwhm) THEN sigma = sig/2.35 ELSE sigma = sig

```

```

;Faktor 1 for odd size
f=[s(0) mod 2, s(1) mod 2, s(2) mod 2]

mid=[s(0)/2 + f(0),s(1)/2 + f(1),s(2)/2 + f(2)]
arr=FltArr(mid(0),mid(1),mid(2))

fak=2.*sigma^2
fak2=(2.*!pi)^(3./2.)*sigma^3

;Create 1/8 Sphere
FOR i=0,mid(0)-1 DO BEGIN
  FOR j=0,mid(1)-1 DO BEGIN
    FOR k=0,mid(2)-1 DO BEGIN
      arr(i,j,k)= Exp(-((i*scale(0))^2+(j*scale(1))^2+(k*scale(2))^2)/fak)/fak 2
    ENDFOR
  ENDFOR
ENDFOR

arr2=FltArr(s(0),s(1),s(2))

;Mirror Subarrays to create whole Sphere
;   3 2 1           1 2 3           0 0 3
;a= 0 0 2 -> Reverse(a,1)= 2 0 0   Reverse(a,2)= 0 0 2
;   0 0 3           3 0 0           3 2 1

arr2(mid(0)-f(0):s(0)-1,mid(1)-f(1):s(1)-1,mid(2)-f(2):s(2)-1)=arr
arr2(mid(0)-f(0):s(0)-1,0:mid(1)-1,mid(2)-f(2):s(2)-1)=Reverse(arr,2)
arr2(0:mid(0)-1,0:s(1)-1,mid(2)-f(1):s(2)-1)=Reverse(arr2(mi
d(0)-f(0):s(0)-1,0:s(1)-1,mid(2)-f(1):s(2)-1),1)
arr2(0:s(0)-1,0:s(1)-1,0:mid(2)-1)=Reverse(arr2(0:s(0)-1,0:s(1)-1,mid(2)-f(2):s(2)-1),3)
Return, arr2

label_END:
END

;-----
;-----Main Program-----
;-----

FUNCTION R_Wisch,im,scale,minn=minn,maxx=maxx
;Convolutes an array with Gaussian Kernel with Dependency To The
Radius
;
;Kay Bente, 7.11.01
;bente@uni-wuppertal.de

```

```
;needs: Kernel_Size.pro
;   Gauss.pro
```

```
;Syntax:
```

```
; image -> image to be smoothed
; scale -> factors from MRImage e.g. [0.9,0.9,1.25]
; minn -> [min_x,min_y,min_z], minn has to be GE 1
; maxx -> [max_x,max_y,max_z]
```

```
time=SystemTime(1)
array=Float(im)
ndims = Size(array, /n_dimensions)
s=Size(array, /Dimensions)
xx=s(0)
yy=s(1)
zz=s(2)
```

```
IF ndims GT 3 THEN BEGIN
    Print,'Pleasy only arrays with 3 or less dimensions'
    Print,'0 returned'
    Return, 0
ENDIF
```

```
kerneldims = Replicate(1L, ndims)
```

```
FOR dimcnt=0L, ndims-1 DO BEGIN
```

```
;-----Convol in
```

```
x-----
```

```
IF dimcnt EQ 0 THEN BEGIN
    IF maxx(0) EQ 0 THEN GOTO, stepout
    Print,'Convol in x'
    IF minn(0) EQ maxx(0) THEN GOTO, old_fashion
    ss_max=Kernel_Size(scale(dimcnt),10,maxx(0))
    l_arr=FltArr(xx+ss_max+1,yy,zz)
    l_arr((ss_max+1)/2,0,0)=array

    FOR t=0,xx-1 DO BEGIN
        r=Abs(xx/2.-t)      ;Get Radius
        fwhmm=minn(1)+((maxx(0)-minn(0))*r/(xx/2.)) ;Calculate FWHM
        ss=Kernel_Size(scale(dimcnt),10,fwhmm) ;Calculate KernelSize
        kernel=Gauss(ss,fwhmm,scale=scale(dimcnt),/FWHM);Build Kernel
    (1D)
        large_kernel=Rebin(kernel,ss,yy,zz) ;Duplicate Kernel in y & z
        array(t,*)=Rebin(large_kernel*l_arr(t+(ss_max+1)/2-1-ss/2:
t+(ss_max+1)/2-1+ss/2,*,*),1,yy,zz)*ss
        ;Rebin calculates mean -> Multiply*ss
```

```

ENDFOR
GOTO, stepout
ENDIF

```

```

;-----Convolution in

```

```

y-----

```

```

IF dimcnt EQ 1 THEN BEGIN

```

```

IF maxx(1) EQ 0 THEN GOTO, stepout

```

```

  Print,'Convolution in y'

```

```

  IF minn(1) EQ maxx(1) THEN GOTO, old_fashion

```

```

  ss_max=Kernel_Size(scale(dimcnt),10,maxx(1))

```

```

  l_arr=FltArr(xx,yy+ss_max+1,zz)

```

```

  l_arr(0,(ss_max+1)/2,0)=array

```

```

    FOR t=0,yy-1 DO BEGIN

```

```

      r=Abs(yy/2.-t)      ;Get Radius

```

```

      fwhmm=minn(1)+((maxx(1)-minn(1))*r/(yy/2.)) ;Calculate FWHM

```

```

      ss=Kernel_Size(scale(dimcnt),10,fwhmm) ;Calculate KernelSize

```

```

      kernel=Gauss(ss,fwhmm,scale=scale(dimcnt),/FWHM);Build Kernel

```

```

(1D)

```

```

      kernel=Reform(kernel,[1,ss,1]) ;Erect Kernel along y-axis

```

```

      large_kernel=Rebin(kernel,xx,ss,zz) ;Duplicate Kernel in x & z

```

```

      array(*,t,*)=Rebin(large_kernel*l_arr(*,t+(ss_max+1)/2-1-ss/

```

```

      2:t+(ss_max+1)/2-1+ss/2,*),xx,1,zz)*ss

```

```

      ;Rebin calculates mean -> Multiply*ss

```

```

    ENDFOR

```

```

    GOTO, stepout

```

```

  ENDIF

```

```

;-----Convolution in

```

```

z-----

```

```

IF dimcnt EQ 2 THEN BEGIN

```

```

IF maxx(2) EQ 0 THEN GOTO, stepout

```

```

  Print,'Convolution in z'

```

```

  IF minn(2) EQ maxx(2) THEN GOTO, old_fashion

```

```

  ss_max=Kernel_Size(scale(dimcnt),10,maxx(2))

```

```

  l_arr=FltArr(xx,yy,zz+ss_max+1)

```

```

  l_arr(0,0,(ss_max+1)/2)=array

```

```

    FOR t=0,zz-1 DO BEGIN

```

```

      r=Abs(zz/2.-t)      ;Get Radius

```

```

      fwhmm=minn(2)+((maxx(2)-minn(2))*r/(zz/2.)) ;Calculate FWHM

```

```

      ss=Kernel_Size(scale(dimcnt),10,fwhmm) ;Calculate KernelSize

```

```

      kernel=Gauss(ss,fwhmm,scale=scale(dimcnt),/FWHM);Build Kernel

```

```

(1D)

```

```

      kernel=Reform(kernel,[1,1,ss]) ;Erect Kernel along z-axis

```

```

      large_kernel=Rebin(kernel,xx,yy,ss) ;Duplicate Kernel in x & y

```

```

        array(*,*,t)=Rebin(large_kernel*I_arr(*,*,t+(ss_max+1)/2-1-s
s/2:t+(ss_max+1)/2-1+ss/2),xx,yy,1)*ss
        ;Rebin calculates mean -> Multiply*ss
    ENDFOR
    GOTO, stepout
ENDIF

```

old_fashion:

```

s=Kernel_Size(scale(dimcnt),3,maxx(dimcnt))
kernel=Gauss(s,maxx(dimcnt),scale=scale(dimcnt),/FWHM)

```

```

;Make 1D-Kernel 3D
kerneldims(dimcnt)=s
kernel = Reform(kernel, kerneldims, /overwrite)

```

```

; convolve the input array (in the first step) or the intermediate
; result with kernel:

```

```

array = Convolve(Float(Temporary(array)), kernel)
kerneldims[dimcnt] = 1L ;Reset KernelDims to [1,1,1]

```

```

stepout:
ENDFOR

```

```

I_arr=0
Print,'Time needed: ',SystemTime(1)-time
Return, array
END

```