

GammaLib - Action #1731

Feature # 1729 (Closed): Add support to smooth sky maps

Use low-level FFT classes to implement GSkyMap smoothing

03/03/2016 10:46 PM - Knödseder Jürgen

Status:	Closed	Start date:	03/03/2016
Priority:	Normal	Due date:	
Assigned To:	Knödseder Jürgen	% Done:	100%
Category:		Estimated time:	0.00 hour
Target version:	1.5.0		
Description			
The low-level FFT classes should be used to implement GSkyMap smoothing			
Related issues:			
Related to GammaLib - Feature # 1768: Investigate whether we can interface Ga... In Progress 04/18/2016			

History

#1 - 06/21/2016 10:01 PM - Knödseder Jürgen

- Target version set to 1.2.0

#2 - 10/07/2016 10:17 PM - Knödseder Jürgen

One possibility is to implement a GFft2d class for performing a 2-dimensional fast fourier transform. The class would store the fourier transform coefficients, allow operations, and provide methods for forward and backward transformations. A possible use case could look like this (this makes use of a ndarray, see #1768):

```
GNdarray a(10,5);
GNdarray b(10,5);
GFft2d fa(a);
GFft2d fb;
fb.forward(b);
GFft2d fc = fa * fb;
GNdarray c = fc.backward();
```

#3 - 10/07/2016 10:17 PM - Knödseder Jürgen

- Related to Feature #1768: Investigate whether we can interface GammaLib with NumPy added

#4 - 10/16/2016 11:43 PM - Knödseder Jürgen

- Status changed from New to In Progress

- Assigned To set to Knödseder Jürgen

- % Done changed from 0 to 70

I implemented the FFT from the GNU Scientific Library. Two classes have been added:

- GFFt which performs a FFT on a n-dimensional array of type GNdarray
- GFFtWavetable which is a helper class for GFFt that contains the trigonometric coefficients for a factorisation

The class so far operates only on 1-dimensional arrays since the GSL does not provide support for more-dimensional arrays. Implementation of such support should however not be too complicated.

#5 - 10/17/2016 12:45 AM - Knödseder Jürgen

Here a Fortran code of a 2D FFT:

```
C
C Transform X lines of C array
c
c On 10 May 2010, the index IW was modified.
c
  IW = 2 * L + INT ( LOG ( REAL ( L ) ) ) + 5

  CALL CFFTMF(L, 1, M, LDIM, C, (L-1) + LDIM*(M-1) +1,
1  WSAVE(IW), 2*M + INT(LOG(REAL(M))) + 4,
2  WORK, 2*L*M, IER1)
  IF (IER1 .NE. 0) THEN
    IER = 20
    CALL XERFFT ('CFFT2F',-5)
    GO TO 100
  ENDIF
C
C Transform Y lines of C array
C
  IW = 1
  CALL CFFTMF (M, LDIM, L, 1, C, (M-1)*LDIM + L,
1  WSAVE(IW), 2*L + INT(LOG(REAL(L))) + 4,
2  WORK, 2*M*L, IER1)
  IF (IER1 .NE. 0) THEN
    IER = 20
    CALL XERFFT ('CFFT2F',-5)
  ENDIF
```

with

- L is the number of elements in the first dimension
- M is the number of elements in the second dimension
- LDIM is the number of elements in the first dimension and corresponds to the stride

The CFFTMF is shown below and calls the 1D function CMFM1F:

```

SUBROUTINE CFFTMF (LOT, JUMP, N, INC, C, LENC, WSAVE, LENSAB,
1  WORK, LENWRK, IER)
C
  INTEGER LOT, JUMP, N, INC, LENC, LENSAB, LENWRK, IER
  COMPLEX C(LENC)
  REAL WSAVE(LENSAB) ,WORK(LENWRK)
  LOGICAL XERCON
C
  IW1 = N+N+1
  CALL CMFM1F (LOT,JUMP,N,INC,C,WORK,WSAVE,WSAVE(IW1),
1  WSAVE(IW1+1))
  RETURN
END
```

with

- LOT is the number of sequences to be transformed
- JUMP is the integer increment of the first elements of two consecutive sequences

- N is the integer length of each sequence to be transformed
- INC is the integer increment of two consecutive elements within the same sequence

$$C(L * JUMP + J * INC + 1) = \sum_{K=0}^{N-1} C(L * JUMP + K * INC + 1) * \exp(-i * J * K * 2 * \pi / N)$$

where $i = \text{SQRT}(-1)$.
 $J = 0, \dots, N-1$
 $L = 0, \dots, \text{LOT}-1$

#6 - 10/17/2016 03:56 PM - Knödseder Jürgen

- % Done changed from 70 to 90

The Gfft class now also supports 2-dimensional arrays.

Code has been merged into devel.

What remains is the implementation of the operators, and the usage of the Gfft class for map smoothing in GSkyMap.

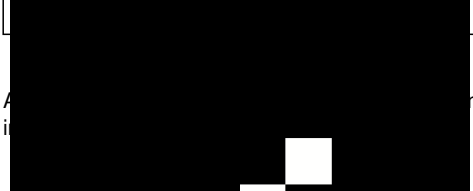
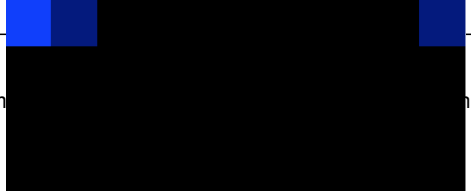
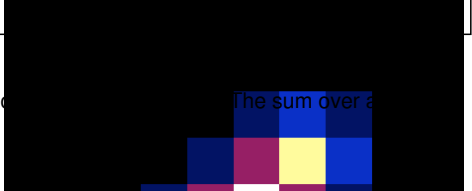
#7 - 10/17/2016 04:57 PM - Knödseder Jürgen

- File input.png added

- File kernel.png added

- File smoothed.png added

Here a test sequence to illustrate that smoothing of a 2-dimensional image works (this also illustrates how the smoothing kernel needs to be aligned):

Input image	Kernel	Smoothed image
 <pre data-bbox="81 1556 555 2067"> # Allocate and set 2-d array array = gammalib.GNdarray(10, 10) for i in range(3,7): array[i,i] = 1.0 ref = array.sum() # Allocate and set 2-d kernel. The kernel needs to be normalized # to unity and the centre of the kernel needs to be at pixel [0,0], # and it needs to be wrapped around to negative indices kernel = gammalib.GNdarray(10, 10) kernel[0,0] = 0.4 # 0.4 kernel[0,1] = 0.1 kernel[1,0] = 0.1 kernel[0,9] = 0.1 kernel[9,0] = 0.1 # 0.2 kernel[1,1] = 0.05 kernel[9,1] = 0.05 kernel[9,9] = 0.05 </pre>		 <p>The sum over a</p>

```
kernel[1,9] = 0.05

# Smooth 2-d array using FFT
fft_array = gammalib.GFft(array)
fft_kernel = gammalib.GFft(kernel)
fft_smooth = fft_array * fft_kernel

# Backtransform
smooth = fft_smooth.backward()

# Test sum
sum = smooth.sum()
self.test_value(sum, ref)

# Store in sky map
map = gammalib.GSkyMap('CAR','CEL',0.0,0.0,-1.0,1.0,10,10)
for iy in range(10):
    for ix in range(10):
        map[ix+iy*10] = smooth[ix,iy]
map.save('test_fft.fits', True)
```

#8 - 03/03/2017 10:23 AM - Knödlseeder Jürgen

- Target version changed from 1.2.0 to 1.3.0

#9 - 06/06/2017 10:25 PM - Knödlseeder Jürgen

- Target version changed from 1.3.0 to 1.4.0

#10 - 07/31/2017 11:10 PM - Knödlseeder Jürgen

- Target version changed from 1.4.0 to 1.5.0

#11 - 10/17/2017 05:14 PM - Knödlseeder Jürgen

- Status changed from In Progress to Closed

- % Done changed from 90 to 100

The GSkyMap::smooth() method was added to accomplish the job.

So far the method supports smoothing using a uniform disk kernel and smoothing using a Gaussian kernel.

Files

input.png	19.4 KB	10/17/2016	Knödseder Jürgen
kernel.png	19.4 KB	10/17/2016	Knödseder Jürgen
smoothed.png	19.8 KB	10/17/2016	Knödseder Jürgen