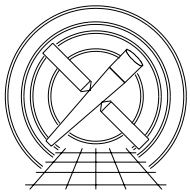

MIT Kavli Institute **Chandra X-Ray Center**

MEMORANDUM
May 11, 2010

To:	Jonathan McDowell, SDS Group Leader
From:	Glenn E. Allen, SDS
Subject:	Sub-pixel event-positioning spec
Revision:	0.1
URL:	http://space.mit.edu/CXC/docs/docs.html#subpix
File:	/nfs/cxc/h2/gea/sds/docs/memos/subpix_spec_0.1.tex

1 Sub-pixel event positioning

1.1 Description

The size of the point spread function of a point source observed with the ACIS detectors is determined by several factors, which include the size of the point spread function of the mirrors, the size of the pixels on the ACIS CCDs, the introduction of a uniform random deviate to the CCD coordinates when computing the detector coordinates and, subsequently, the sky coordinates (i.e. "pixel randomization"), and the accuracy to which the pointing direction can be reconstructed.

Pixel randomization was introduced to avoid aliasing effects that can produce unusual features in the shape of the image of a point source for some observations. This randomization can be disabled by setting the `acis_process_events` parameter `rand_pix_size` = 0.

The size of an ACIS pixel undersamples the point spread function of an on-axis point source. As a result, the use of the ACIS detectors can degrade the quality of an image of a source, particularly if events are assumed to occur at the centers of the pixels for which they are reported. Tsunemi et al. (2001), Mori et al. (2001), Li et al. (2003), and Li et al. (2004) describe algorithms that can be used to more accurately locate the centroids of certain events based upon the distribution of charge in the "event islands.[1]"

This spec describes the implementation of the energy-dependent sub-pixel event-positioning algorithm ("EDSER") of Li et al. (2004) in the tool `acis_process_events`. This algorithm is the one that works best for GRADED and non-GRADED mode event data.

1.2 Input

1. A Level 1 or 2 event-data file (acis*evt1.fits, acis*evt1a.fits, acis*evt2.fits)

2. A sub-pixel ARD file (acisD*subpix*.fits)

[1] An event island, the quantity named `PHAS` in a Level 1 event-data file, contains the pulse-height distribution in a 3 pixel $\times$ 3 pixel region centered upon the pixel in which an event is reported. In VFAINT mode, `PHAS` is a 5×5 array instead of a 3×3. The `PHAS` information is not telemetered for GRADED mode data. However, the `FLTGRADE`, a scalar representation of the distribution of charge in the central 3×3, is telemetered for both GRADED and non-GRADED modes. Only one of sub-pixel event-positioning algorithms requires `PHAS` (i.e. the algorithm "CSDSER"). All of the rest use the `FLTGRADE`.

1.3 Output

1. An event-data file in which the coordinates DETX and DETY and, perhaps, X and Y have been updated. Note that the coordinates CHIPX, CHIPY, TDETX, and TDETY are not modified.

1.4 Parameters

1. `infile,s,a,"",,,"Name of input event-data file"`
2. `outfile,s,a"",,,"Name of output bad-pixel file"`
3. `subpixfile,s,h,"CALDB",,,"Name of input sub-pixel file (CALDB | NONE | none | <filename>)"`
4. `apply_subpix,b,h,"yes",,,"Apply the sub-pixel location adjustment?  (yes | no)"`

1.5 Processing

In the standard ACIS pipeline, the sub-pixel event-positioning algorithm should be performed after the ENERGY and FLTGRADE have been computed since the algorithm depends upon these quantities. The calculation should occur before the detector coordinates DETX and DETY are calculated since these coordinates depend upon the results of the sub-pixel positioning. If the sky coordinates X and Y are calculated, then the calculation should use the updated values of DETX and DETY.

Perform the following tests before processing begins.

- Verify that the input files exist. If they do not, then exit with an error message.
- If clobber = no, then verify that the output file does not exist. If it does, then exit with an error message.
- Verify that the parameter rand_pix_size = 0. If it is not, then exit with an error message.
- Verify that the parameter stop = det, tan, or sky. If it is not, then exit with an error message.

Perform the following steps, in sequence, for each event.

1. Use the value of CCD_ID to select the appropriate HDU in the sub-pixel ARD file and use the value of FLTGRADE to select the appropriate row in that HDU (see sec. 2).
2. Use the expressions

$$\mathtt{CHIPX}' = \mathtt{CHIPX} + (\Delta X_{i+1} - \Delta X_i)\left(\frac{E - E_i}{E_{i+1} - E_i}\right) + \Delta X_i \tag{1}$$

and

$$\mathtt{CHIPY}' = \mathtt{CHIPY} + (\Delta Y_{i+1} - \Delta Y_i)\left(\frac{E - E_i}{E_{i+1} - E_i}\right) + \Delta Y_i \tag{2}$$

to calculate the real-valued, sub-pixel locations of CHIPX′ and CHIPY′, respectively. Here E is the ENERGY of the event and

$$E_i = \mathtt{ENERGY}_i, \tag{3}$$
$$E_{i+1} = \mathtt{ENERGY}_{i+1}, \tag{4}$$
$$\Delta X_i = \mathtt{CHIPX\_OFFSET}_i, \tag{5}$$
$$\Delta X_{i+1} = \mathtt{CHIPX\_OFFSET}_{i+1}, \tag{6}$$
$$\Delta Y_i = \mathtt{CHIPY\_OFFSET}_i, \text{ and} \tag{7}$$
$$\Delta Y_{i+1} = \mathtt{CHIPY\_OFFSET}_{i+1}, \tag{8}$$

where the quantities on the right-hand sides of equations 3–8 are from vectors in the ARD file (see sec. 2).

The values of i and $i+1$ are the ones that satisfy the relationship

$$E_i \leq E < E_{i+1}. \tag{9}$$

The valid ranges for i and $i+1$ are from 0 to NPOINTS $-$ 2 and from 1 to NPOINTS $-$ 1, respectively.[2] Therefore, if $E > E_{\texttt{NPOINTS}-1}$, then use $i =$ NPOINTS -2 and $i+1 =$ NPOINTS -1 (i.e. extrapolate instead of interpolate). Since E should always be greater than zero and since $E_0 = 0$, in no case shall $i < 0$.

3. Use the values of CHIPX′ and CHIPY′ to calculate the detector coordinates DETX and DETY and, depending on the value of the parameter stop, the sky coordinates X and Y.

1.6 Caveats

1. A sub-pixel event-positioning algorithm cannot produce a point spread function that is better than the point spread function produced by the mirrors and by the accuracy of the reconstruction of the pointing direction of the telescope. It is not a deconvolution algorithm.
2. At this time, the point spread function for data which has had this sub-pixel event-positioning algorithm applied is not calibrated.
3. The use of a sub-pixel event-positioning algorithm can influence the fraction of the events inside a source extraction region. At present, this effect is not included in the response tools.

2 Sub-pixel positioning ARD

The sub-pixel event-positioning algorithm requires input that is specified in an ARD file. Aside from a null primary header, the ARD file includes ten separate HDUs (one for each CCD), with one binary table per HDU. Each binary table includes the following columns.

- FLTGRADE
- NPOINTS
- ENERGY
- CHIPX_OFFSET
- CHIPY_OFFSET

There is one row for each FLTGRADE. The columns ENERGY, CHIPX_OFFSET, and CHIPY_OFFSET contain vectors for each row. These vectors are used to perform the linear interpolation and extrapolation described in section 1.5. Only the first NPOINTS elements in the vectors should be used for this process. The remaining elements, if any, contain zeroes. The information in the ARD file is based on the data in Figure 4 of Li et al. (2004).

References

Li, J., Kastner, J. H., Prigozhin, G. Y., & Schulz, N. S., 2003, ApJ, 590, 586

Li, J., Kastner, J. H., Prigozhin, G. Y., Schulz, N. S., Feigelson, E. D., & Getman, K. V., 2004, ApJ, 610, 1204

Mori, K., Tsunemi, H., Miyata, E., Baluta, C. J., Burrows, D. N., Garmire, G. P., & Chartas, G., 2001, in New Century of X-ray Astronomy, ed. H. Inoue & H. Kunieda, Vol. 251, 576

Tsunemi, H., Mori, K., Miyata, E., Baluta, C., Burrows, D. N., Garmire, G. P., & Chartas, G., 2001, ApJ, 554, 496

[2] NPOINTS is the name of a column in the ARD file (see sec. 2).