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NICMOS Calibration Pipeline: Processing Associations of Exposures

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Abstract. The Hubble Space Telescope (HST) Near Infrared Camera and Multi-Object Spectrometer (NICMOS) will often produce multiple exposures of a given target, usually for the purposes of measuring and removing thermal background emission and for rejecting cosmic rays. The processing of these associated images presents new challenges to the HST data processing pipelines, which heretofore operated only on single images. In this paper we describe the concept of associated observations and how they will be processed collectively by the NICMOS calibration pipeline.

1. Introduction

The basic or "atomic" element within the HST ground system has been the "exposure." In this mode, a single exposure results in a single "dataset," which is given a unique name and is pipeline processed, calibrated, and archived separately from all other datasets. The second-generation HST instruments present many instances in which the combination of data from two or more exposures is necessary to create a scientifically useful data product. For NICMOS, for example, the HST thermal background is expected to vary temporally, therefore multiple exposures (dithered for small targets and "chopped" onto blank sky for larger targets) will be necessary to measure and remove this background. Multiple exposures will also be used to reject cosmic rays, as well as for constructing mosaics of large angular-sized targets. While this has been standard practice in existing data reduction schemes for ground-based IR observations, it is a new paradigm for the HST ground system.

2. What is an Association?

An association is a means of identifying a set of exposures as belonging together and being, in some sense, dependent upon one another. The association concept permits these exposures to be calibrated, archived, retrieved, and reprocessed as a set rather than as individual exposures. Associations are defined by observers in their proposals. Typical usage will be:

- to obtain multiple exposures at a single sky position for the purpose of identifying and rejecting cosmic ray events,
- to obtain a sequence of slightly offset (dithered) exposures to improve flat fielding, avoid bad pixels, build a mosaic for large angular-sized targets, and, for sufficiently compact targets, to remove the background illumination, and
- to obtain a sequence of observations in which the field of view is chopped between the target and one or more offset sky regions to remove the background illumination for large angular-sized targets.

The individual exposures are logically linked through the use of an association table, which contains information on each exposure and is used by the data processing system to identify the contents of an association.

A set of predefined observing patterns are provided for NICMOS dithered, chopped, and combined dither-chop observations. All patterns are open ended; the observer specifies the total number of desired positions to be executed. The observer also specifies the size of the dither and/or chop movements to be executed between successive exposures within the pattern.

3. NICMOS Data Calibration

The NICMOS data calibration process is divided into two stages. Stage 1 (CALNICA) calibrates individual exposures without information from other members of the association. It performs the typical instrumental calibration steps such as dark-current subtraction, non-linearity corrections, and flat-fielding. Stage 2 of calibration (CALNICB) only operates on associated images that have previously gone through CALNICA processing, and creates combined images for each distinct (non-overlapping) pointing within the association. The CALNICB output images are generically referred to as "mosaics."

All stages of calibration propagate and update (as appropriate) data arrays containing statistical errors, data quality flags, number of samples, and exposure time per pixel that accompany the actual science image.

The CALNICA and CALNICB software is written in ANSI C. Data I/O is accomplished using IRAF I/O library functions. A set of C-to-IRAF interface routines (developed at STScI) provides the linkage between the calibration software and the IRAF libraries.

4. CALNICB Processing

The operation of CALNICB is driven by an association table, which is a FITS binary table that contains a list of the individual exposures that make up the association. This design allows observers to modify the contents of an association by adding, deleting, or editing individual exposures and then reprocessing. This is easily accomplished by modifying the association table and (if desired) the files containing the individual exposures.

CALNICB processing is divided into the following major steps:

- read the list of input images from the association table and load all data,

- determine processing parameters from header keywords,
- combine multiple images (if any) at individual pattern positions,
- measure and remove background illumination,
- create mosaic images from overlapping pattern positions, and
- create an updated output association table.

4.1. Determining Processing Parameters

CALNICB processing parameters are determined from FITS header keyword values in the input images. If none of the predefined observing patterns was used, then all the images in the association are multiple exposures at a single pointing. If a pattern was used, CALNICB determines how many and which images were taken at each pattern position, and which of the positions correspond to target or sky observations. The type of pattern used (if any) also determines the number of output mosaic images that will be produced. If either no pattern or a pure dither pattern was used, there will be a single output mosaic image made up of either the multiple images at a single pointing (the no pattern case) or a true mosaic of the entire set of overlapping dither images. Pure chop patterns result in one mosaic image for the target position, as well as one mosaic image for each of the offset sky (chop) positions. Combined dither-chop patterns result in one mosaic for the target dither sequence and one for the sky dither sequence.

4.2. Combining Multiple Exposures

In the event that the observer requests multiple exposures at each pattern position, the individual images are combined. Cross-correlation techniques are used to measure and correct for any misregistration between images that may be present due to, for example, small amounts of telescope drift. The combining procedure computes the average value of the n samples for each image pixel, excluding flagged pixels, and uses iterative sigma-clipping to reject deviant values. The number of samples used, as well as the total integration time, at each pixel are updated in their respective data arrays.

4.3. Background Estimation and Removal

Background removal is accomplished in two steps: first, a scalar background level is determined from the images in the association and subtracted from them; second, a reference image containing measured spatial variations in the HST thermal background is subtracted from each association image.

The scalar background level is first determined for each association image, and then a final value is determined by averaging the individual results. Iterative sigma clipping is used at both levels of averaging to reject deviant values that may be the result of cosmic ray events or sources contained within the images. For dithered patterns, all positions are used in the scalar background computation. For chopped or combined dither-chop patterns, only the off-target positions are used.

4.4. Mosaicking

A mosaic image is constructed by:

- determining the relative offsets of each image (using cross-correlation techniques),
- using the relative offsets to determine the total size of the mosaic and the position of each image within the mosaic,
- resampling (via bi-linear interpolation) each image into its appropriate location within the mosaic stack, and
- combining (collapsing the stack) the samples for each pixel in the mosaic.

The process of combining the samples for each mosaic pixel is identical to that used earlier for combining multiple images at a given pattern position; the average pixel value is computed using iterative sigma-clipping to reject outliers, as well as excluding flagged pixels. Values for the number of samples and integration time arrays are updated as appropriate.

4.5. Output Table

The output association table contains a copy of all the information from the input table plus new columns of information derived during processing. The new information includes a flag to indicate whether or not a particular image was used in the background calculation, the background level computed for the image, and the x and y pixel offsets of each image relative to its reference image.

CALNICB will allow an observer to reuse an output table as input to the program in order to reprocess a given association using different parameters. The observer can modify the table to indicate whether or not certain images should be used in the background calculation, manually set the background level and skip the run-time calculation, or set specific image offset values and skip the run-time calculation of offsets. An example association table for a five position spiral-dither pattern is shown in Table 1. Note that the last row of the table pertains to the output mosaic image.

Table 1. Association Table.

Name	Type	Prsnt	BkgImage	MeanBkg (DN/sec)	XOffset (pixels)	YOffset (pixels)
N2RUSG01T	EXP-TARG	yes	yes	0.293	0.00	0.00
N2RUSG02T	EXP-TARG	yes	yes	0.292	36.20	0.00
N2RUSG03T	EXP-TARG	yes	yes	0.292	36.20	36.20
N2RUSG04T	EXP-TARG	yes	yes	0.293	0.00	36.20
N2RUSG05T	EXP-TARG	yes	yes	0.293	−36.20	36.20
N2RUSG010	PROD-TARG	yes	no	INDEF	INDEF	INDEF