MultiDrizzle Overview & Future Plans

Anton Koekemoer *(STScI)*

Dither strategies

- unresolved sources vs extended objects
- large-scale mosaicing
- Combining dithered data

MultiDrizzle

- Design and implementation

Tweakshifts

- Shift refinement techniques

Current / Future plans

- Expanded ACS associations
- Improved CR rejection algorithms
- Continued MultiDrizzle support for ACS, STIS, NICMOS,WFPC2,WFC3
- Archive/VO-related enhancements

Philosophies of Dithering

Stars & other unresolved objects:

- May be preferable to dither only on sub-pixel scales
- Fully sample intra-pixel response function, provide better photometry
- Cost: hot pixels, bad columns not adequately removed, affecting <1-2% of the pixels

Extended objects:

- Intra-pixel response not a major issue, therefore dither by at least a few pixels to move hot pixels & bad columns around
- Sub-pixel sampling may still be desirable; add these to integer-pixel shifts
- Large ACS distortion (~7%) changes the sub-pixel sampling across chip (10-pixel shift at center has extra 0.5-pixel shift at corner) --> small shifts

Large-scale mosaicing:

- cover the WFC chip gap (~ 50 pixels)
- cover an area larger than the chip size
- Obtain enough dithers to average out any changes in sub-pixel sampling

Dithering in Practice

Sub-pixel sampling considerations:

- Pixels are 0.025” for HRC, 0.05” for WFC, 0.045/0.09” for WFPC2
- PSF is generally well sampled with 1/2-pixel shifts (sometimes 1/3 pix)
- Intra-pixel sampling may demand smaller shifts
- Pointing precision of HST (~3 mas) places a limit for very small shifts

Number of dither steps:

- 1/2-pixel steps ideally use 4-point box to sample 4 quadrants of pixel
- Sometimes observing time is limited, so observers use line dithers:
  - 2-point (1/2-pixel along one axis)
  - 3-point (1/3-pixel along one axis)
  - these will provide better sampling along one direction than another
- If intra-pixel sensitivity is crucial, may want to consider 9-point (1/3-pix) or perhaps even finer dithering
- To cover chip gap, often use 2 or 3-point large-scale line dither, with smaller scale 2-point sub-pixel dither at each position

Combining Dithered Data

Alignment

- Image headers have commanded (**not** actual) offsets; accurate to ~2-3 mas [in 3-gyro as well as 2-gyro!]
- Corresponds to ~0.1 pix for WFC (0.2 pix for HRC) - often adequate
- More accurate alignment can be obtained with Tweakshifts - see later

Cosmic ray rejection

- Run drizzle on all the aligned exposures to remove distortion
- Create a clean (median) image from the aligned exposures
- Transform ("blot") the clean image back to the frame of each exposure
- Compare difference to create CR masks:

$$|\text{original} - \text{median}| > \text{gradient} + \text{Nsigma} * (\text{RN}^2 + \text{median} + \text{background})^{1/2}$$

Final image combination

- Run drizzle again to combine all the exposures, now using the CR masks
- Final image is effectively a weighted sum, where masked pixels contribute with zero weight

What is MultiDrizzle?

Philosophy:

- Different steps (alignment, median creation, CR rejection, final drizzling etc) are very labour-intensive and require lots of manual book-keeping
- Goal of MultiDrizzle is to provide a seamless interface to these steps, taking care of all book-keeping, while allowing access to all parameters
- Default parameters are set to provide useful results for the majorit of datasets following standard dither recommendations (eg 4-point box patterns, comparable exposure times etc)
- Parameters can be adjusted for special cases

Implementation:

- Written as a script within Pyraf
- Interacts with old IRAF Dither package (e.g., driz_cr to remove CRs)
- Also contains completely new scripts, eg “numcombine” - a python-based version of imcombine that is much more powerful and can combine literally hundreds of ACS/WFC images without memory problems

MultiDrizzle Steps - The 7-Fold Way

1. Static Mask:
   - identify very negative pixels that may affect the median process
2. Sky subtraction:
   - subtract the lowest sky value from multi-chip data
3. Separate drizzling:
   - drizzle to produce registered, distortion-corrected images of all exposures
4. Median:
   - combine all the registered images to produce one clean (median) image
5. Blot:
   - transform the median back to each input exposure
6. Driz_cr:
   - compare median input with original exposure to creare CR masks
7. Final drizzle:
   - drizzle all exposures again, using CR masks to create combined image

MultiDrizzle - Current Status

Pyraf/STSDAS MultiDrizzle - current v2.5.5 (10 March 2005):

- ACS: all observation modes WFC, HRC, SBC, fully tested
- WFPC2: all observation modes, mostly tested
- STIS: all imaging modes (CCD, MAMAs), fully tested
- NICMOS: all imaging modes, partially tested

Pipeline MultiDrizzle:

- Same code base as STSDAS version, frozen every ~3-6 months
- Runs on all ACS associations in pipeline
- MultiDrizzle pipeline products include:
  - Drizzled, combined images, often suitable for science directly as-is
  - CR information in FLT file DQ arrays
  - Improved astrometric header keywords in FLT files
  - Header values in drizzled image containing history of drizzle parameters
- Intent is for MultiDrizzle pipeline products to be usable for science as-is, but the data can always be re-run through MultiDrizzle off-line with different parameters if needed for specific applications

Tweakshifts

Motivation:

- While 2-3 mas accuracy is sufficient for many purposes, it still corresponds to ~0.1 - 0.2 pixel, and can thus be improved

Shift measurement method:

- catalog-based (currently either DAOfind or SExtractor)
- cross-correlation
- wavelet transforms

Generic uses for Tweakshifts:

- Refine relative shifts between exposures in an association
- Refine absolute astrometry, by comparing with external catalog (eg GSC2)

Absolute astrometric improvement:

- Most ACS images have several GSC2 objects → can improve to <0.3-0.5” absolute astrometry by using Tweakshifts in catalog-based mode
- Currently exploring pipeline implementation

Current Support - MultiDrizzle

MultiDrizzle Maintenance:

- Continued response to user problems (generally installation-related)
- Interaction between Instruments and Software groups to resolve pipeline-related problems:
  - Occur rarely
  - Typically due to problematic data, eg science exposures with EXPTIME=0

MultiDrizzle Testing:

- Functional / regression testing:
  - Run a subset of datasets nightly, the full set is run once/week
  - Ensure that the code still successfully executes after modifications
  - Augment with new datasets that have revealed problems in the code
- Scientific testing:
  - Explore optimum parameters to ensure good default/pipeline behaviour for the widest possible range of datasets
  - Quantify accuracy of astrometry, photometry, CR rejection

Expanding ACS Associations

Previous definition of ACS associations:

- Observations obtained using dither pattern or CR-SPLIT
- Exposures are not associated if obtained using POS TARGs
- However, observers often use POS TARGs:
  - may have a specific need not covered by the dither patterns
  - generally still expect/require the data to be associated and combined

Expansion of ACS associations:

- Provide additional combined datasets from exposures with POS TARGs
- Build association from all exposures that satisfy the following:
  - same filter
  - within the same visit
- Benefits of initially restricting this to exposures in the same visit:
  - same guidestars, therefore header shifts can be used
  - provides limitation on the size of the largest offset (less than ~1')
- Some caveats, related to moving targets and certain calibration proposals, in which case the exposures do not need to be associated

Longer-Term Plans

Scientific prioritization / planning:

- Cross-interaction between Instruments and Software Divisions, and discussions with user community
- Develop “wishlist” of ideas
- Carry out subsequent prioritization and implementation

MultiDrizzle enhancements:

- Refine CR rejection algorithms:
  - improved CTE treatment
  - single-image CR rejection? (useful for datasets with only 2-3 exposures)
- STIS spectroscopy
- NICMOS iterative background correction

Archive/VO-related improvements:

- Further expand associations to multiple visits
- May allow MultiDrizzle parameter changes in archive interface

Future Enhancements – CR rejection

Current CR rejection scheme:

- Uses driz_cr, which has the following features:
  - essentially based on sigma-clipping, combined with a slight "softening" from flux gradients in the image to avoid clipping bright concentrated source
  - works best for large numbers of images, although with sufficient testing & exploration of parameter space, also gives acceptable results for 3-4 images
- Main limitations:
  - in 2-3 image datasets, doesn't always succeed when there is just 1 good pixel
  - doesn't reject CTE tails on CRs
  - to work well, need to create sub-sampled image → resource-intensive

Two possible improvements:

- CTE tails can be rejected in a second more stringent pass, examining only pixels along the read-out direction from CRs identified in the first pass:
  - relatively easy to implement
  - some preliminary experiments have been done by Koekemoer/Busko
- Consider rejecting CRs on single images, (eg Laplacian edge detection, ...) prior to running MultiDrizzle

MultiDrizzle Enhancements - STIS

Current situation:

- MultiDrizzle works for all STIS imaging modes
- All 3 STIS cameras: CCD, NUV-MAMA, FUV-MAMA

Eventual goal – spectroscopy:

- Many observers dither along the slit to mitigate hot pixels; CTE from hot pixels is along slit direction, thus dithering is important in obtaining good spectra
- Some observers also dither along wavelength direction to better sample the spectral line spread function
- Some studies currently underway:
  - examine changes required (e.g., new keywords) as well as the extent of code modifications
  - examine scientific usefulness of incorporating this capability: would the resulting products be usable as-is for the majority of science data?
- This work to be prioritized along with enhancements for other instruments

MultiDrizzle Enhancements - NICMOS

Current capabilities:

- MultiDrizzle can now read all types of NICMOS data, and can perform the basic tasks of CR rejection and image combination
- Main limitation is that background correction is treated the same way as for optical CCDs, which is incorrect for NICMOS

Improved background correction:

- Create a first-pass image, assuming static background correction
- Run object detection / identification on the resulting combined image
- Use the objects to create a "mask" excluding any regions with flux
- For each exposure, fit the remaining unmasked background and subtract
- Re-do the drizzle combination
- Iterate the above if necessary

Status:

- Tests underway to investigate required software changes

Archive/VO-Related Enhancements

Absolute Astrometry improvements:

- Experiments to date find improvement in absolute astrometry accuracy to ~0.3", ie about 10x improvement

Further expand associations – include adjacent visits

- Benefits:
  - Move HST data products from large mosaic programs into the "VO era"
- Two potential concerns:
  - different guidestars, and the need to very accurately align to < 0.1 pixel; can be solved in principle by running Tweakshifts in a specialized fashion
  - Processing resource issues (much larger images than currently); can be solved by letting the user specify a central RA,Dec and a limiting radius around this

Parameter control in archive interface:

- Can further increase scientific value of products (observers can select exactly the parameters they want, eg orienation, pixel scale, etc)
- Might be appropriate for implementation in "Hubble Legacy Archive"