MOSAIC: an IDL Software Package for Manipulating Collections of Images

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Abstract. We have developed a powerful, versatile image processing and analysis software package called MOSAIC, designed specifically for the manipulation of digital astronomical image data obtained with two-dimensional array detectors. The software package is implemented using the Interactive Data Language (IDL), and incorporates new methods for processing, calibration, analysis, and visualization of astronomical image data, stressing effective methods for the creation of mosaics from collections of individual exposures, while at the same time preserving the photometric integrity of the original data. Since IDL is available on many computers, the MOSAIC software runs on most UNIX and VAX workstations with the X-Windows or SunView graphics interface.

1. Introduction

The MOSAIC software was written for the purpose of processing and analyzing images from the $58 \times 62$ pixel Goddard 5 - 18 $\mu$m infrared array camera system (Gezari et al. 1988, 1992). However, there is no restriction on the size or type of images, and the software has been used to create mosaics of images from other camera systems, such as $512 \times 512$ pixel CCD images. For examples of MOSAIC results see Gezari et al. 1992, Gezari 1992, Telesco and Gezari 1992.

2. Capabilities and Methods

The major tasks performed by MOSAIC are, input of a collection of images, creation of mosaics of the images, analysis, display and hardcopy of the results. Each of these major functions provides an extensive set of operations which the user can interactively apply to the data. The user interface is three-button mouse controlled, menu driven, and window based, so that the user can naturally follow a logical sequence of required processing steps. Future plans for the software include taking full advantage of X-Windows widgets for the user interface. For the more experienced user, the MOSAIC procedures and functions can be invoked directly at the IDL command level, permitting specialized operations that may not be in the presented list of options.

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The creation of a mosaic image consists of four basic steps: 1) pre-processing, which includes formatting and flat-fielding of the individual images, residual background offset corrections, bad pixel detection and masking, and other corrections (e.g., de-striping), 2) alignment of images by correlation of common spatial features, then referred to as a “raw mosaic”, 3) matching of pixel intensities in overlapping image areas, 4) averaging the overlapping areas (or splicing images) to form a final mosaic image with improved signal-to-noise (SNR), called the “averaged mosaic”.

The spatial arrangement or alignment of images is accomplished by the following methods, selected as options by the user. If accurate relative coordinates of the images are known they can be immediately arranged, by entering the coordinates interactively or reading a file containing the coordinates. If relative coordinates are not known, there must be some overlap between images in order to proceed. The user can choose between interactive or automatic creation of the raw mosaic of images, or a combined approach. One interactive method allows the user to align images at a common source feature by mouse controlled cursor selections. This method has an automatic counterpart which can be used when the alignment point is a peaked source in the images. In such cases the centroid of the source is automatically computed in each image and then used to automatically align the images.

Another interactive method allows direct manipulation of the images, similar to a desktop graphics environment, and this visually corresponds to "dragging" the image with the mouse. While being dragged, a blinking image is displayed, alternating with the other images in the window, so that the user can visually correlate the overlaps. The automatic counterpart to this image blinking-dragging option is the use of image cross-correlations to determine the optimal relative positions of the overlaps. In this automatic mode, the computer maximizes the cross-correlations of the image overlaps, thereby achieving the same or better results as the interactive approach. All operations for creating the raw mosaic occur on a fractional pixel grid.

The MOSAIC system also allows the user to choose image scaling, smoothing and magnification for the display of the raw mosaic. Other interactive options include the ability to “pop” and “push” displayed images in a raw mosaic, highlight the borders of images, display header information, or determine the noise (SNR) and background (sky) levels. The pixel values of individual images or all overlapping images can be displayed per user selects, as either arrays of numbers, mean and standard deviation in a box, graphs of profile cuts at any angle through the images, or as histograms showing the pixel value distribution.

After the raw mosaic is arranged spatially, the pixel intensity values in the overlapping image regions are often not the same. The pixel values in overlapping image areas can in most cases be matched effectively with the constraint of applying only linear transformations to the intensities (a factor plus a constant). This matching of intensity transformations can be performed either in a manual/interactive or automatic approach. The user may specify two points in the image stack, usually one point on a source the other on sky, to use in the computation of the linear transform. The average of pixel values in the two specified areas of a chosen size then defines the linear transformation to be applied to all the images which overlap at the two points. An automatic method uses linear-least-squares
fits between corresponding pixels to compute the linear transformations. However, such pixel to pixel matching can cause erroneous fits when image noise levels are high. A more robust approach is to automatically match the means and variances of the pixel intensity distributions in the overlapping regions. This approach recognizes the fact that the images are already spatially arranged so that the matching of pixel values can be accomplished statistically as a group. Carrying this approach further leads to the method of matching by histograms. Since histograms of the overlapping regions give the full distribution of pixel values, the act of matching the cumulative histogram graphs accomplishes the desired matching of image levels. A record of what linear transformations have been applied is kept in the IDL structured array of data, with the pixel intensities, relative image locations in mosaic space, positional coordinates and other parameters. The results of all processing can be saved at any stage of the effort and later restored to continue processing.

After the raw mosaic is spatial arranged and matched, the images are combined by averaging or splicing, on a whole or fractional pixel grid, to form the averaged/spliced mosaic image. As a user selected option, bad pixels can be ignored during averaging, such as at the edges of images. All of the information resulting in the successful creation of the final image is retained with the averaged mosaics. The system also allows averaged mosaics or any other images to be combined and manipulated together, creating another raw mosaic to form an even larger averaged mosaic, or just a group of images for analysis.

The display of an averaged mosaic and generation of hard copy is a module offering many user selectable options. Contour levels can be overlaid on the color image, or the data displayed with contours alone. Overlaid contours can even be from other image data of different resolution. The display format for mosaic images include positional coordinates of three types: relative pixels, relative arcseconds, or absolute R.A. and DEC. Other display options include: linear, geometric, or logarithmic scaling of data, selection of color palletes and adjustment of color tables, insertion of hardcopy titles, labeling and marking of sources. All specifications for the display of an image are saved in an IDL structure, and so they can be restored to redisplay the image exactly as it was specified. Color hardcopy of the displayed mosaic image is produced by output of PostScript graphics files, in 32 level grey-scale or 256 pseudo-colors mode.

Final mosaic images obtained at different wavelengths can be aligned to form a multi-wavelength mosaic image stack, creating a “data cube” which can then be used for further analysis, such as formation of true-color images, deriving source spectra at any point in the image, or to derive model results displayed in the form of images (e.g. color temperatures, dust column densities, line-of sight extinction, etc.). The creation of a multi-wavelength mosaic is performed in three steps: 1) spatial alignment of images, 2) relative calibration of overlapping regions, 3) extracting the intersection of all images. Arithmetic and function operations can then be applied to the intersection region in the stack of images. The MOSAIC software also has an interactive interface to the DeConv Tool package (Városi and Landsman 1993) for the purpose of instrument point spread function deconvolution.
3. Summary of MOSAIC Functions and Capabilities

PRE-PROCESSING:

- Cataloging and retrieval of observational image data files
- Background subtraction
- Flat-fielding
- Residual sky (background) subtraction
  - sky level matching
    - linear transform
    - histogram matching
  - synthetic sky frame
- De-striping and other corrections
- Bad pixel masking and removal

 MOSAIC CREATION:

- Create raw mosaic of images by relative offsets
  - define coordinate system
  - enter relative coordinate offsets
  - read coordinate offsets from file
  - define scanning pattern of offsets
- Interactive raw mosaic creation:
  - aligning at common point
  - blink/drag image to position
- Automatic raw mosaic creation:
  - align at point source centroids
  - offsets by optimal cross-correlation of image overlaps
- Match image intensity levels
  - match using two points
  - linear least squares of overlap pixel values
  - match means and variances of pixels in overlap
  - match cumulative histograms of overlaps
- Manipulate raw mosaic
  - move (blink-drag) image or group of images
  - pop/push images
  - add/remove images
  - save/restore raw mosaic
  - scale and display images (linear/log/smoothing)
  - magnify or reduce display of images
  - display image borders
  - display header information
  - estimate statistics: noise level, FWHM, etc.
  - show fluxes in aperture
  - plot histograms of images and overlaps
  - plot profile cuts of overlapping images
  - average/splice all or subset of images
  - save averaged/spliced mosaic
DISPLAY of FINAL MOSAIC IMAGE:
- Display image and contour plots
  - overlay contour levels
  - overlay contours from a different image
  - relative/absolute coordinates
  - change scaling (linear/log, min/max)
  - zoom subregion
  - smooth data (low pass filter, Gaussian convolution, etc.)
  - mark/label sources
  - save/restore all display specifications
  - save/restore final mosaic image
- Show fluxes (in aperture) and statistics
- Determine source centroids and FWHM
- Plot profile cuts
- Hardcopy (PostScript)
  - contour maps
  - 32-level grey scale images
  - 256-level pseudo-color images

COLOR MANIPULATION:
- Select, create and save color tables
- Adjust pixel value to color table mapping

MOSAIC ANALYSIS:
- Create multi-wavelength mosaic image stack
- Normalization/calibration
- Plot spectrum at any point
- Plot profiles at any angle
- Compute arithmetic and functions of images in stack
- Output multi-wavelength data cube
- Deconvolution

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References

Városi, F. and Landsman, W. B. 1993, this volume