Astronomical Data Analysis Software and Systems XV
ASP Conference Series, Vol. 351, 2006
C. Gabriel, C. Arviset, D. Ponz and E. Solano, eds.

IDP3, An IDL-based Interactive Astronomical Data Analysis Package

Elizabeth Stobie, Anthony Ferro

University of Arizona, Tucson, AZ 85721

Abstract. Image Display Paradigm #3 (IDP3) is a versatile interactive astronomical image analysis package written in the Interactive Data Language (IDL)[1]. It was originally developed for the Near Infrared Camera and MultiObject Spectrometer Instrument Definition Team (NICMOS IDT) to support image analysis and point spread function subtraction for high precision photometry and astrometry. Over the years its functions have been expanded to support several types of two-dimensional astronomical data. In this presentation we explore IDP3, its design, and its current features including the capability to execute without an IDL license.

1. Introduction

In early 1997 the NICMOS IDT needed an interactive program to subtract point spread functions from NICMOS data for high precision photometry and astrometry. By using IDL, with its powerful array-oriented language, numerous mathematical analysis routines, and graphical display functions, we were able to create a flexible and structured design while delivering the desired application on schedule. The program structure is very general giving us the freedom to expand its capabilities well beyond the initial intent.

2. Program Design

IDP3 was designed to be a very dynamic and interactive program with a flexible framework, receptive to continued expansion of functionality as requested by users.

2.1. Platform support

IDP3 runs on multiple platforms with varying display resolutions and various CPU configurations. The most common platforms are: Sun Solaris, Linux, Apple Mac OSX, and MS Windows.

[1]IDL *(http://rsinc.com/idl)* is distributed by Research Systems, Inc (RSI), a member of the ITT Space Systems Group of ITT Industries.

2.2. User Interface

The program environment is defined to be entirely interactive. User interaction is through the primary IDP3 window and subwindows directly or indirectly activated from it. There is no command line interface, although the user has access to the IDL command line during program execution. This feature, however, is not available when using the IDL Virtual Machine (IDL VM)[2] rather than a fully licensed IDL installation. Batch processing is limited to the stack operators. The position and size of the multiple, interacting windows is controlled by the user. Global parameter definition is done via an editable file, `idp3_preferences`, loaded upon program initialization. Most of these parameters may also be edited during program execution in the Edit Parameters Window.

2.3. Process Communication

Process communication is accomplished by the sharing of the root structure, `info`, (the main window's User Value) through the windows' event handlers. No COMMON blocks are used. Global actions automatically update all affected active windows.

2.4. Data Manipulation

When images are loaded into IDP3 they are stored in the `images` substructure of `info`. Any manipulations of these images are instantly reflected in the main display/work area as well as the currently active subwindows. The data in the images structure remain unchanged. Every action causes the main display and Region of Interest (ROI) to be rebuilt from the original data. This eliminates the need for previous actions on the data to be undone, e.g., translation and resampling. The resultant images in the main display and the ROI are only preserved when saved to disk and/or IDP3 memory (`images` substructure).

2.5. Documentation

The help file associated with the main window of IDP3 gives an overview of the program and its features. All of the subwindows have their own help files which give the details of that application. The help files are accessed via a Help button in each window. Also, the Multiband Imaging Photometer for Spitzer (MIPS) group at the University of Arizona has developed a web-based tutorial for IDP3[3].

2.6. Code Reuse

Where feasible routines are used from the IDL Astronomy User's Library at the Goddard Space Flight Center[4], as well as other well known repositories of IDL code including: David Fanning for color manipulation routines[5], Craig

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[2]The IDL Virtual Machine is a free IDL runtime utility available with IDL 6.0 and above from RSI at *http://rsinc.com/idlvm*.

[3]The IDP3 tutorial may be found at *http://mips.as.arizona.edu/MIPS/IDP3*.

[4]The IDL Astronomy User's Library is available from *http://idlastro.gsfc.nasa.gov*.

[5]David Fanning's IDL website is *http://www.dfanning.com*.

Markwardt for curve and surface fitting routines[6], and Marc Buie for resampling routines[7]. This has allowed faster development with well-tested public routines.

2.7. Support for the IDL VM

RSI has made the IDL VM available free of charge with IDL Version 6.0 and above. (See footnote 2.) Use of the IDL VM, which does not require an IDL license, is limited to activating precompiled save sets with no command line interface to IDL and no capability for compiling code. All IDP3 messages that are normally written to the IDL terminal window are saved to an array. These messages may be displayed in the IDP3 Text Window.

3. Program Capabilities

IDP3 continues to evolve as new features are requested by its users. Its current major capabilities are:

- Multiple images may be individually scaled, resampled, translated, and rotated in the main display/work area simultaneously.
- Data may be aligned [translation and rotation] by visual or statistical [world coordinates, centroid solutions] criteria.
- Image combination, convolution, editing, blinking, mask definition, and source catalog overlay are available from the main display window.
- Supported arithmetic operations on images include: add, subtract, multiply, divide, invert (1/image), average, minimum, and absolute value.
- The ROI provides a tool for intensive examination of sub-regions of the main display. Cross sections, radial profiles, noise profiles, histograms, contour maps, image statistics, spreadsheets, aperture photometry, gaussian profile fitting, photocentric moment solutions, and surface plots may be performed from the ROI.
- Individual images may have associated masks as well as a composite mask for the ROI display. Pixels of a specific value may be masked. Not a Number (NaN) values are automatically masked.
- Data may be resampled by bi-linear, apodized bi-cubic, or spline bi-cubic interpolation or pixel replication with the option to conserve flux. Subpixel image translation is done by bi-linear or apodized bi-cubic interpolation.
- All modifications to the individual images that comprise a saved output image are documented in its header.
- FITS [primary header and data unit (PHDU), multi-extension image, and 3-D image], HDF, TIFF [2-D, 3-D], and PICT images are supported on input. FITS [PHDU and single image extension] are supported on output.
- The state of all loaded images may be saved to a parameter file which may be restored in IDP3 in a later session.

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[6]Craig Markwardt's IDL website is *http://cow.physics.wisc.edu/~craigm/idl*.

[7]Marc Buie's IDL website is *http://www.lowell.edu/users/buie/idl*.

4. Availability

The source code for IDP3, as well as many other NICMOS routines, is available from the NICMOS web site: *http://nicmos.as.arizona.edu/software*. Those who wish to use the IDL VM must also download the file containing the IDP3 compiled code, `idp3.sav`. The command to execute IDP3 with the IDL VM is: `idl -vm=idp3.sav`.

5. Conclusions and Future Plans

IDP3 was initially developed for a specific task but because of careful software engineering and forethought it has grown to be a very useful and extensible tool. Its capabilities are continuing to expand as its user base grows, and it has been used with a wide variety of astronomical data. Some of its diverse uses include:

- Coronagraphic imaging survey of protostellar and debris disks. Data source: HST NICMOS coronagraphy.
- Studying dust grain evolution in protostellar environments and YSO disks via imaging polarimetry. Data source: HST NICMOS and ACS.
- Probing the AGN and multiple-nuclear structure of the ultra-luminous IR galaxy meger NGC 6240. Data source: (a) HST NICMOS and (b) KECK II adaptive optics broad and narrow band imaging.
- Constraining the size of the nucleus of the ULIRG MRK23, and probing the starburst region in the galactic halo. Data source: HST NICMOS and WFPC-2.
- Searching for brown dwarf and EGP companions to nearby, young, and late spectral type stars. Data source: (a) HST NICMOS, (b) KECK II AO, (c) Palomar/PALAO, and (d) CFHT.
- Characterization of ultra-cool companions to M - G stars. Data source: HST STIS.
- Computation of unresolved point source image centroids and accurate aperture photometry. Data source: Spitzer IRAC and MIPS.
- The forward scattering aerosols and refractive properties of the Cytherian (Venus) atmosphere at very low phase angles using high resolution imagery of the 2004 June transit of Venus. Data source: The Transition Region and Coronal Explorer Spacecraft.
- Solar coronal electron density measurements during the 2003 November total solar eclipse, from $1 < r < 15$ solar radii. Data source: contemporaneous observations from (a) the SOHO C2 Coronagraph and (b) Airborne imagery from a band-limited CCD aboard a Boeing 747-400.

IDP3 will continue to evolve as we expand its functionality within the limits of available funding. Current planned additions include ability to repair bad pixels by block average or Gaussian weighted average and improve the help facility.

Acknowledgments. We would like to acknowledge Dyer Lytle who, while working with the NICMOS Group at the University of Arizona, designed and developed the protype of IDP3. We are grateful to Rodger Thompson, Glenn Schneider, Murray Silverstone, and Dean Hines for their helpful discussions, suggestions, and user feedback. Funding for this software development has been provided by NASA grants NAG 5-3042 and NAS 2-26555 to the NICMOS IDT.