AIPS MEMO NO. 51

The NRAO AIPS Project - A Summary

Alan H. Bridle

15 May 1987

The NRAO Astronomical Image Processing System (AIPS) is a software package for interactive (and, optionally, batch) calibration, construction, display and analysis of astronomical images made from radio interferometric data using Fourier synthesis methods. Design and development of the package began in Charlottesville in 1978; it presently contains over 600,000 lines of code and about 200 distinct applications "tasks", representing approximately 30 man-years of effort since 1978. The AIPS group in Charlottesville has five full-time scientist/programmers, and several other computing and scientific staff with partial responsibility to the AIPS effort. The group is responsible for the code design and maintenance, for documentation aimed at users and programmers, and for exporting the code to about 200 non-NRAO sites that have requested copies of AIPS. It currently offers AIPS installation kits for VMS and for generic UNIX systems, with updates available quarterly.

AIPS has been the principal tool for display and analysis of both two- and three-dimensional radio images (i.e., continuum "maps" and spectral line "cubes") from NRAO's Very Large Array (VLA) since early in 1981. It has also provided the main route for self-calibration and imaging of VLA continuum data. It contains facilities for display and editing of data in the aperture, or u-v, plane; for image construction by Fourier inversion; for deconvolution of the point source response by CLEAN and by maximum entropy methods; for image combination, filtering, and parameter estimation; and for a wide variety of TV and graphical displays. It records all user-generated operations and parameters that affect the quality of the derived images, as "history" files that are appended to the data sets and can be exported with them from AIPS in the IAU-standard FITS (Flexible Image Transport System) format. AIPS implements a simple command language which is used to run "tasks" (i.e. subprograms) and to interact with text, graphics and image displays. A batch mode is also available. The package contains over 1.5 Mbytes of "help" text that provides on-line documentation for users. There is also a suite of printed manuals for users and for programmers wishing to code their own applications "tasks" within AIPS.

Since 1983, when AIPS was selected as the primary data reduction package for the Very Long Baseline Array (VLBA), the scope of the AIPS effort has been expanded. By the end of 1987, AIPS will embrace all stages of radio interferometric calibration, both continuum and spectral line, as well as the geometric and delay calibrations required for very long baseline interferometry. The AIPS package should then contain most of the calibration and editing functions hitherto performed only in the VLA's on-site Dec-10 computer, in addition to the post-calibration capabilities outlined above. At that point, AIPS will be able to perform all data reduction steps that are normally done after correlation of, and fringe-fitting to, radio interferometric data.

An important aspect of AIPS is its portability. It has been designed to run, with minimal modifications, in a wide variety of computing environments. This has been accomplished by the use of generic FORTRAN wherever possible and by the isolation of system-dependent code into well-defined groups of routines. AIPS tries to present as nearly the same interface to the user as possible when implemented in different computer architectures and under different operating systems. NRAO has sought this level of hardware and operating system independence in AIPS for two main reasons. The first is to ensure a growth path by allowing AIPS to exploit computer manufacturers' advances in hardware and in compiler technology relatively quickly, without major recoding. (AIPS was developed in ModComp and Vax/VMS environments with Floating Point Systems array processors, but was migrated to vector pipeline machines in 1985. Its portability allowed it to take prompt advantage of the new generation of vector and vector/parallel optimizing compilers offered in 1986 by manufacturers such as Convex and Alliant). The second is to service the needs of NRAO users in their home institutes, where available hardware and operating systems may differ substantially from NRAO's. By doing this, NRAO supports data reduction at its users' own locations, where they can work without the deadlines and other constraints implicit in a brief visit to an NRAO telescope site. The exportability of AIPS is now well exploited in the astronomical community; the package is known to have been installed at some time on about 175 different computers worldwide, and is currently in active use for astronomical research on at least 114 different machines. AIPS has been run on Cray and Fujitsu supercomputers on Convex and Alliant "minisupercomputers", well as on the full variety of Vaxen and MicroVaxen, and on Apollo, Charles River Data Systems, Data General, Jupiter, MassComp, Nord, Ridge and SUN products.

Similarly, a wide range of digital TV devices and printer/plotters has been supported through AIPS's "virtual device interfaces". Support for such peripherals is contained in well-isolated subroutines coded and distributed by the AIPS group or by AIPS users elsewhere. TV devices in use at AIPS sites include IIS Model 70 and 75, IVAS, AED, Apollo, Aydin, Comtal, DeAnza, Graphica, Graphics Strategies, Grinnell, Image Analytics, Jupiter, Lexidata, Ramtek, RCI Trapix, Sigma ARGS, SUN, Vaxstation/GPX and Vicom. Printer/plotters include Versatec, QMS/Talaris, Apple, Benson, CalComp, Canon, Digital Equipment, Facom, Hewlett-Packard, Imagen, C.Itoh, Printek, Printronix and Zeta products. The standard interactive graphics interface in AIPS is the Tektronix 4012.

The principal users of AIPS are VLA and VLBI Network observers. A survey of AIPS sites carried out early in 1987 showed that 46% of all AIPS data processing worldwide is devoted to VLA data reduction. Outside NRAO, AIPS is extensively used for other astronomical imaging applications, however. 72% of all AIPS processing done away from NRAO involves data from instruments other than the VLA. The astronomical applications of AIPS that do not involve radio interferometry include the display and analysis of line and continuum data from large single-dish radio surveys, and the processing of image data at infrared, visible, ultraviolet and X-ray wavelengths. About 5% of all AIPS processing involves astronomical data at these shorter wavelengths, with 15 sites using AIPS more for such work than for

radio. 8 sites use AIPS exclusively for non-radio work.

Some AIPS use now occurs outside observational astronomy, e.g. in visualization of numerical simulations of fluid processes, and in medical imaging.

The distinctive features of AIPS that have attracted users from outside the community of radio interferometrists are its ability to handle many relevant co-ordinate geometries precisely, its emphasis on display and analysis of the data in complementary Fourier domains, the level of support given by NRAO to exporting the package to different computer architectures, and its extensive documentation. As well producing user- and programmer- oriented manuals for AIPS, the group publishes a newsletter that is sent to over 700 AIPS users outside NRAO soon after each quarterly "release" of new AIPS code. There is also a mechanism whereby users can report software bugs or suggestions to the AIPS programmers and receive written responses to them; this provides a formal route for user feedback to the AIPS programmers and for the programmers to document difficult points directly to individual users. The AIPS group also hosts biannual workshops for AIPS users. NRAO knows of over 230 AIPS "tasks", or subprograms, that have been coded within the package outside the observatory.

The AIPS group has developed a package of benchmarking and certification tests that process standard data sets through the dozen most critical stages of interferometric data reduction, and compare the results with those obtained on NRAO's own computers. This "DDT" package is used to verify the correctness of the results produced by AIPS installations at new user sites or on new types of computer, as well as to obtain comparative timing information for different computer architectures and configurations. It has been extensively used as a benchmarking package to guide computer procurements at NRAO and elsewhere.

Future development of AIPS will include interactive (TV-based, graphics-based) editing of data in the u-v and time-baseline domains; fuller support of AIPS in Crays under the COS and UNICOS operating systems; development of algorithms for wide-field mapping (especially for observations at meter and longer wavelengths); additional spectral line applications; more efficient tasks for sequential image deconvolution and self calibration (using both CLEAN and maximum entropy methods); efficient use of large memory resources on computer systems that have them; improved visualization methods for many-dimensional images (e.g., spectral line data); increased used of computer network services for software distribution, bug reporting and fixing, etc. and for other interactions between the AIPS group and AIPS users worldwide.

Further information on AIPS can be obtained by writing to the AIPS Group, National Radio Astronomy Observatory, Edgemont Road, Charlottesville, VA 22903-2475, U.S.A.