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Adaptive Optics Software on the CfAO Web Page

Andreas Quirrenbach, Vesa Junkkarinen, Rainer Köhler

University of California, San Diego, Center for Astrophysics and Space Sciences, Mail Code 0424, La Jolla, CA 92093-0424, USA

Abstract. The Center for Adaptive Optics maintains a web site, which serves as a repository for software and tools related to adaptive optics. We describe the purpose and structure of this web site, and give brief descriptions of the currently available software packages. In the future, the CfAO web page can evolve into a complete data reduction toolbox for adaptive optics observations.

1. Purpose and Structure of the CfAO Software Web Server

The Center for Adaptive Optics (CfAO) is a Science and Technology Center, funded by the National Science Foundation. It was established in November 1999 with the mission "to advance and disseminate the technology of adaptive optics in service to science, health care, industry, and education". The activities of the CfAO cover a broad range of research topics related to adaptive optics; they also include programs to distribute know-how and tools for adaptive optics to the scientific community. (One of these programs is an annual summer school series on adaptive optics for astronomy and vision science.)

Among the goals of the CfAO is the distribution of software for adaptive optics, with the intention to prevent duplication of efforts by CfAO members and others, and to give researchers in adaptive optics a place to distribute their software. One of the CfAO member institutions, the University of California, San Diego, hosts and maintains a web server[1], from which a number of software packages can be downloaded. The software on this site comes from the scientists and institutions affiliated with the CfAO, and from other scientists and institutions interested in sharing AO software with the astronomical and general scientific community. The philosophy is not to initiate a coherent software development effort, but rather to gather independently developed packages, and to make them accessible at one site. Therefore no attempts have been made to homogenize the programming languages used, or the platforms on which the programs run. All software packages have been tested and documented by the respective author(s); in many cases we have carried out additional testing, and added brief user guides or instructions. The software and its associated documentation is placed in directories accessible by anonymous ftp. Web pages provide convenient links to the directories and/or files for downloading.

[1] `http://babcock.ucsd.edu/cfao_ucsd/software.html`

2. Available Packages

The main criterion for the inclusion of software on the CfAO web page has been their utility for a broad range of users of adaptive optics systems, with a bias towards packages that CfAO scientists are using for their own research. The following eight packages are currently available for download from the CfAO web site:

- `A++` This complex package is a tool to generate wavefront reconstruction matrices for adaptive optics systems, which are used to calculate the deformable mirror commands from the wavefront sensor data. `A++` was originally written by Walter Wild, and modified by the University of Chicago AO group. `A++` has an extensive user manual. Many astronomical AO systems with Shack-Hartmann wavefront sensors currently in operation use versions of Walter Wild's reconstruction matrix.
- `AO Simulation Package` This software, written by François Rigaut, simulates an adaptive optics system. The user sets the parameters of the AO system and telescope. The software calculates the closed-loop performance of the telescope and AO system and simulates the observation of a star using a phase screen model for the Earth's atmosphere.
- `AOTOOLS` This set of scripts written by Eric Steinbring simplifies the reduction of near-infrared data acquired with an adaptive optics system. (Most current astronomical AO systems are equipped with near-infrared focal plane instruments.) The package consists of IRAF cl scripts that need both IRAF and STSDAS. It installs as an external IRAF package with help files.
- `idac` This is a large package of software for adaptive optics data reduction using blind deconvolution. The software has been written and documented by Stuart Jefferies, Julian Christou, Keith Hege, and Matt Cheselka (see Jefferies & Christou 1993; Christou et al. 1995). Blind deconvolution is a technique that allows the point spread function to be determined by the analysis of multiple images of a single science field, which may or may not contain point sources. Blind deconvolution has the advantage that many separate telescope pointings to acquire observations of a calibration point source for PSF estimation are not required. Blind deconvolution is in many cases preferable to separate PSF star observations due to the time-variable nature of the atmosphere and PSF.
- `Rainer's Binary/Speckle Package` This is a software package written by Rainer Köhler to reduce speckle data on binary and triple stars (Köhler et al. 2000). Speckle methods take advantage of short exposures to "freeze" the atmospheric seeing, and the binary information is preserved in speckles, or bright regions. Each image consists of a large number of speckles, and considerable analysis must be done to extract scientifically useful measurements from the raw images. The package works completely in the Fourier domain; it has also been used with great success for adaptive optics observations of binary stars.
- `StarFinder` This software package, written by Emiliano Diolaiti and colleagues at Bologna Observatory, carries out some of the fundamental tasks in the analysis of adaptive optics data (Diolaiti et al. 2000). It provides both point spread function estimation and, by using the PSF, astrometry

and photometry in crowded stellar fields. Bright stars are used for an initial estimate of the point spread function. The PSF estimate and the set of detected faint stars are then iteratively improved until the entire field is analyzed.

- `Strehl Code/FitStars` This software, contributed by Theo ten Brummelaar, is used to analyze an adaptive optics observation of a point source to estimate the Strehl ratio. The Strehl ratio is the ratio of the peak intensity actually observed to the peak intensity that would be observed if the telescope were operating at the diffraction limit. The Strehl ratio is the most common figure of merit for the performance of an AO system. The package also contains utilities for photometry, astrometry, and PSF fitting of binary star images (ten Brummelaar et al. 2000).
- `Virtual_Telescope` This is an IDL program (with supporting files) written by Eric Steinbring for the simulation of observations, and to predict their signal-to-noise ratio. This tool is designed to simulate a telescope along with its instruments. An artificial field is generated that is deep enough to test even the capabilities of the James Webb Space Telescope (JWST). The telescope itself, its point spread function, and backgrounds for ground or space observations are then simulated.

The first two of these packages (`A++` and the `AO Simulation Package`) are primarily meant to be used by designers and operators of adaptive optics systems. The other packages are more related to observing preparation and data reduction, and address the needs of astronomers who use AO systems for their observing projects.

3. Outlook

In addition to the software packages described above, the CfAO web page contains a few introductory articles on adaptive optics, and links to additional tools that can help to prepare proposals or observing projects. It is also planned to make a number of test data sets available, which can be used to investigate the effects of anisoplanatism in reduced images, and to cross-compare different data reduction and deconvolution algorithms. On a longer time scale, the CfAO web site could evolve into a complete modular AO data analysis toolbox (Quirrenbach 1999). This would require contributions from a larger group of AO users, and a more systematic approach to algorithm development, interface definitions, coding, and documentation. For the near future, the main purpose of the CfAO web page will remain the provision of access to an increasing number of useful software packages and tools, for anyone interested in designing or using adaptive optics systems. With this function, the services provided by the CfAO web page are complementary to those of the large observatories, which provide complete data reduction pipelines and data analysis packages, but with no specific emphasis on adaptive optics.

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