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A User-Friendly Way to Optimize Adaptive Optics: NAOS Preparation Software

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Abstract. The concept of NAOS[1] Preparation Software (PS) enables any user to optimize the adaptive optics (AO) system, independently of his/her level of expertise. The required inputs merely focus on the choice of the astronomical object used to close the AO loop, while hiding technical parameters of the system to the astronomer's view. This is achieved by using *a priori* knowledge of the instrument to select the best configuration. The PS also returns an estimation of the expected performance. For convenient use, the PS is accessible on the World Wide Web throughout Phases I and II of the preparation.

1. Introduction

The preparation of observations to be carried out with adaptive optics systems (esp. NAOS) is more complex than with other instruments, for the following reasons:

- the number of parameters to set is larger than for a simple imager or even a spectrograph. Furthermore, they concern the algorithm which is

[1]Nasmyth Adaptive Optics System for the VLT.

used to optimize the corrected beam and are *a priori* unfamiliar to most observers, while critical for the performance. Usually, it is possible to restrict the number of input parameters by defining observational modes, thus allocating default values to instrument parameters, leaving only a few degrees of freedom to the user. In the case of NAOS there are no such modes, because the inputs may vary in such a range that it is not possible to define a restricted set of use cases. Indeed, the wavelength of observation for the science instrument, as well as the characteristics of the AO reference object, give rise to a very large set of instrument configurations, so that NAOS has to be tuned for each individual case;

- optimizing the instrumental configuration for a given observation highly depends on external conditions, such as the reference object used to close the AO loop, and the turbulence condition in the atmosphere. Furthermore, assumptions made during the preparation about these issues may have to be revised when starting the observation (non-predictability of the turbulence, possible wrong assumptions about the shape or photometry of the reference object);
- the main scheduling criterion is the achievable performance, in terms of Strehl ratio, and there is of course not a one-to-one relation between this criterion and the configuration of the AO system.

This pleads for an advanced user support when the astronomer is to prepare an observation using NAOS. The aim of the PS is to provide the astronomer with a unified interface for everything that pertains to the preparation of the adaptive optics system, from the choice of the reference object to the setting of the needed template[2] parameters. The tool is to be available during the program handling phase, but will also be requested during the observation itself, for on-line performance estimation and possible re-optimization of the AO system configuration. When in Phase I or II of preparation (see contexts of use in section 3.), the astronomer will be able to request the PS via a web server.

2. Features of NAOS PS

Considering the remarks made in the previous section, the design of the PS has to take into account and implement the following features:

Graphical User Interface: available in two forms. During Phases I and II, the PS will be accessible on the Internet via a regular web browser. The on-line version of the PS will have a standard, VLT-compliant interface.

Interface to star catalogues: the user will be able to request remote star catalogues directly from the interface of the PS. The request to the catalogues will take into account information about the science object.

Simulation parameters and user constraints: the atmospheric conditions used for the internal simulation of the AO system will be configurable by

[2]Templates are high-level observation sequences defined for all VLT instruments. Template calls are usually generated through the P2PP tool (cf. section 2.)

the user. It will also be possible to freeze some instrumental parameters of the configuration of NAOS, to ensure that they will not be modified by a possible on-line re-optimization during the observation. For example, the astronomer's knowledge of the scientific issues of the observation may lead him to impose a specific wavefront sensor, either the visible or the infrared one.

Results of the simulation: the PS returns an optimized set of NAOS parameters for the observation specified by the user. The expected image quality is also returned in the form of the PSF and its derivatives.

Interface with the VLT P2PP tool: ESO provides a dedicated preparation tool for Phase II (aka P2PP), which enables to build Observation Blocks that represent the observation program. It will be possible for the user to transfer the results obtained with the PS back into the P2PP tool.

3. Contexts of Use

As said above, the PS will be available to the astronomers from the program proposal to the observation. This implies that several copies of the PS will be available, depending on the context of use.

During Phase I of the preparation, the PS is available for "feasibility analysis". Only a minimum set of inputs is required: for example, one can ask for a performance estimation, only specifying a F1 star with $M_v = 13$, without having to choose an actual object in a catalogue. Phase II uses the same tool but this time it requires detailed inputs, as the result of the PS has to be used to build some Observation Blocks. In both cases, the software is accessed through Internet.

During the observation, the PS may also requested for performance estimation, or for an optimization of an instrumental configuration. This time, the PS is a part of the NAOS operational software, and relies on real-time information for atmospheric conditions and characteristics of reference objects. The request may come from the user, the NAOS Observation Software, or the VLT Scheduler.

4. User Interface

Figure 1 shows an early mock-up of the interface. One may notice that the configuration of the AO system only takes a small part of the panel, while a good third of it is devoted to the choice of the astronomical object which will be used to close the AO loop during the observation. Generally speaking, one tries to emphasize what is relevant to the astronomer, while leaving out the setting of technical parameters to the software. When observing, the GUI is only called if interaction with the user is absolutely necessary, e.g. when the reference object is too peculiar for NAOS to find an optimal configuration.

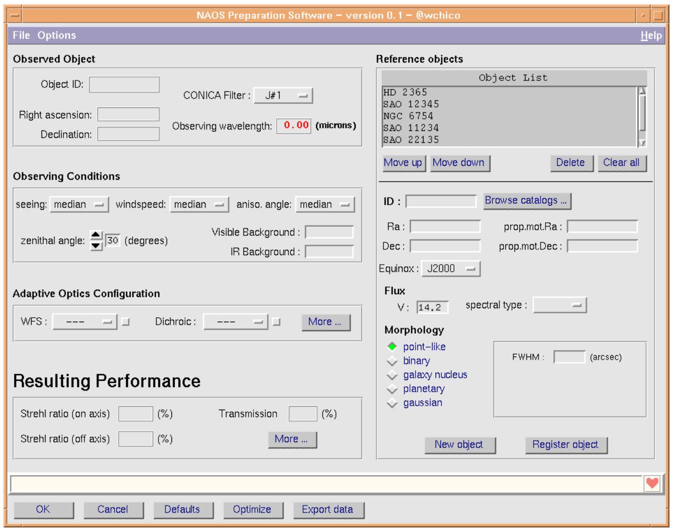

Figure 1. Early design of the NAOS Preparation Software GUI.

5. Internal Conception

To achieve the optimization of NAOS configuration and compute the corresponding, expected performance (in terms of image quality), the knowledge of the instrument is first used to choose the best values for the numerous parameters of the system. This task is devoted to the *Configuration Optimizer*, which uses a set of configurable rules that are parsed according to the user inputs, and possible constraints about the availibility of hardware resources. The rules are written with a simple syntax, and can be easily modified so as to tune the behaviour of the system. A syntactic analyzer based on *lex* and *yacc* tools is first used to translate these rules into core objects that are understandable by the Configuration Optimizer. The output of this sorting phase is a set of suitable NAOS configurations, which should be as small as possible. Indeed, these configurations are then sent to the *Performance Estimator*, which builds an internal, physical model of the instrument and of the atmosphere. It outputs an estimation of the point-spread function, as seen with the AO system in closed loop. The Configuration Optimizer can then make the final decision and choose the best-suited settings for NAOS. Derivated quantities such as encircled energy, FWHM and Strehl ratio are also sent back to the user. The PSF is calculated on-axis, i.e. for the reference object, but an option is available to the user, that gives an estimation of the PSF in the direction of the science object by taking into account the anisoplanetism angle.

6. Conclusion and Perspective

The final design of NAOS Preparation Software has been accepted by ESO in January 1999. Software development will occur in the first half of 2000, so that the PS should be completed by the end of July. It will thus be available for observations to be carried out from the beginning of 2001.