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The Durham Adaptive Optics Simulation Platform (DASP): Current status

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ABSTRACT

The Durham Adaptive Optics Simulation Platform (DASP) is a Monte-Carlo modelling tool used for the simulation of astronomical and solar adaptive optics systems. In recent years, this tool has been used to predict the expected performance of the forthcoming extremely large telescope adaptive optics systems, and has seen the addition of several modules with new features, including Fresnel optics propagation and extended object wavefront sensing. Here, we provide an overview of the features of DASP and the situations in which it can be used. Additionally, the user tools for configuration and control are described.

Code metadata

Current code version	Commit 3a4faa7
Permanent link to code/repository used for this code version	https://github.com/ElsevierSoftwareX/SOFTX-D-18-00002
Legal Code License	GNU Affero General Public Licence v3
Code versioning system used	git
Software code languages, tools, and services used	C, Python, MPI
Compilation requirements, operating environments & dependencies	Linux (full functionality) and OS-X (reduced functionality, including in some GUI elements)
If available Link to developer documentation/manual	http://dasp.readthedocs.io/en/latest/
Support email for questions	a.g.basden@durham.ac.uk

The Durham adaptive optics (AO) simulation platform (DASP) has been under development since the early 1990s. Its current framework was established in 2006 to meet the challenges of modelling the forthcoming extremely large telescopes, with primary mirror diameters of over 20 m. Since 2006, DASP has been regularly developed to improve computational performance, increase simulation fidelity, and expand the number of features that can be modelled. It uses a modular design, allowing new developments and algorithms to be added whilst maintaining compatibility. DASP is developed primarily in Python and C, and uses pthreads and MPI for parallelization enabling modelling of the largest proposed telescopes on reasonable timescales.

1. Motivation and significance

The Earth's atmosphere has a perturbing effect on incident starlight, meaning that the effective spatial resolution of large telescopes (typically anything larger than 20 cm diameter) is limited. By using AO systems, the distorted wavefronts of incident light can be measured and have a correction applied so that the effective resolution is improved, thus enabling scientific observations to be made. Designing an AO system to meet complex scientific requirements is an involved process, and modelling of the system performance is necessary. Additionally, investigation of

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new algorithms, techniques and concepts also requires verification by simulation.

1.1. Scientific contribution of DASP

DASP was developed to meet the needs of AO system designers, and has previously been used to model the expected performance of several of the forthcoming Extremely Large Telescope (ELT) instruments, including MOSAIC [1,2], MAORY [3] and HIRES. Recent developments have also introduced an extended object (wide field-of-view) wavefront sensor module, enabling DASP to be used for the modelling of solar AO systems (e.g. European Solar Telescope [4]). Additionally, existing instruments have also been modelled to demonstrate that proposed novel techniques can improve the AO system performance [5,6].

DASP enables AO system designers to explore the large parameter spaces associated with AO system development, allowing system design trade-offs to be made in an informed manner, with typical parameters including AO system order, number of guide stars, and wavefront sensor pixel scale. DASP is used to design and optimize new AO systems, and to verify performance of existing systems. DASP can be a crucial tool for understanding the AO error budget, allowing cost-effective decisions to be made about the design optimizations that can be performed to allow a given design to meet its required performance targets.

DASP has seen adoption within the AO community, and is now used for forthcoming ELT instruments [3,7], for the 10.4 m Gran Telescopio Canarias, the Kunlun Dark Universe Survey Telescope [8], the Chinese 2.16 m telescope [9] and for the proposed 12 m Chinese Large Optical Telescope.

1.2. Using DASP

DASP can be operated on any Linux computer, and also under the OS-X operating system. Once installed, the user will typically generate a new simulation configuration using the daspbuilder tool, which allows the user to select a number of configuration options covering most AO configurations, including single conjugate AO (SCAO), multi-conjugate adaptive optics (MCAO), ground layer AO (GLAO), laser tomographic AO (LTAO) and multi-object AO (MOAO). This generates the necessary configuration files, which can then be edited by the user. Alternatively, for more complex simulations, a daspsetup tool can be used to graphically design an AO system. This simulation is then executed to model AO performance. A further description of DASP usage is given in Section 3

1.3. Other AO simulations

There are a number of other Monte Carlo AO simulation tools freely available to the community, including YAO [10], CAOS [11], SOAPY [12], MAOS [13] and OOMAO [14]. OCTOPUS [15] is another Monte Carlo AO simulation tool, which is available from the European Southern Observatory upon request. However, none of these offer the combined performance and extended object wavefront sensing capabilities of DASP. In addition, a number of analytical modelling tools also exist, including PAOLA [16] and CIBOLA [17], though these tools are used for rapid prototyping and do not offer high fidelity.

2. Software description

DASP is comprised of a number of science modules, which model discrete parts of an AO system. These include wavefront sensors (including Shack–Hartmann and Pyramid sensors), deformable mirrors (including zonal and modal), atmospheric models, wavefront reconstruction modules, and astronomical object models. This modular design means that it is also possible for the user to add modules which can then be used during a simulation (for example, another wavefront sensor type). These science modules are linked together to represent the flow of information through the AO system, as shown in Fig. 1.

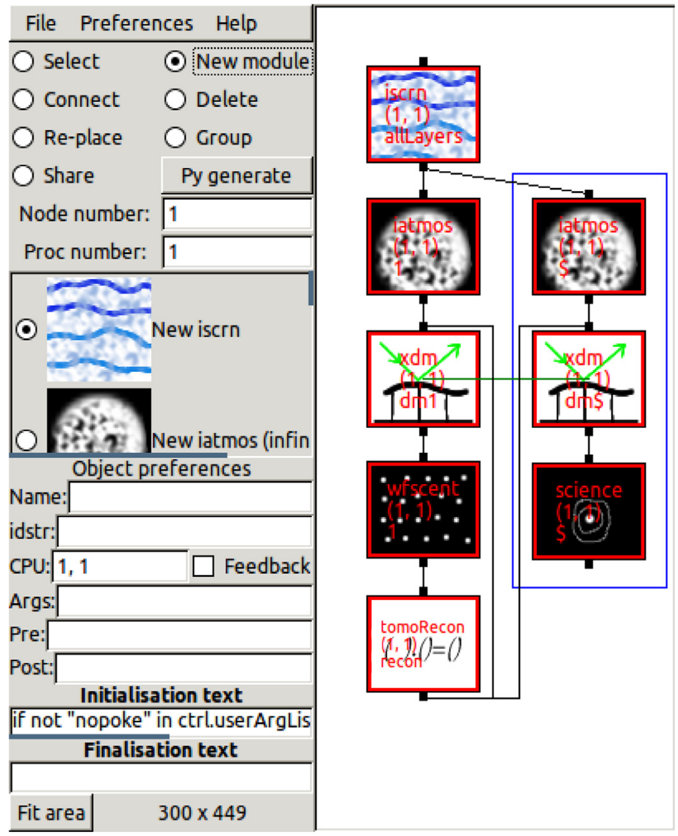

Fig. 1. A screenshot of the daspsetup tool, showing the links between different science modules that create a simulation. This tool can be used to configure an initial simulation, which is then executed from the command line. Configuration of an AO simulation can be complicated when parallelization across multiple computing nodes is required, and the graphical tool simplifies this task.

DASP also contains a number of utility modules, which are used by the science modules, containing the necessary algorithms required by the simulation. User tools are also included, to analyse and display results, to communicate with running simulations, and to configure initial simulations. DASP offers good performance on laptops (for simulation of smaller scale systems, typically up to 10 m class diameter telescopes); and also HPC facilities for ELT modelling. Inter-node communication is based on the Message Passing Interface (MPI).

Once a simulation has been configured, it is run from the command line. After a set number of iterations (typically several thousand, depending on AO system type), the simulation then finishes, providing the user with AO performance metrics. Each iteration represents one simulation time-step, typically set by the integration time of wavefront sensors, of order 1 ms. It is usually necessary to model tens of seconds of real time in order to ensure that results are statistically valid. The simulation will typically run between 10–1000 times slower than real-time, depending on scale