Real-time computing methods for astronomical Adaptive Optics

An iterative, wavelet-based real-time reconstructor for atmospheric tomography

H2020 SOCIETAL CHALLENGES: Secure, clean and efficient energy

PRODUCTIVE SECTOR: Information and Communication Technology

PROBLEM DESCRIPTION

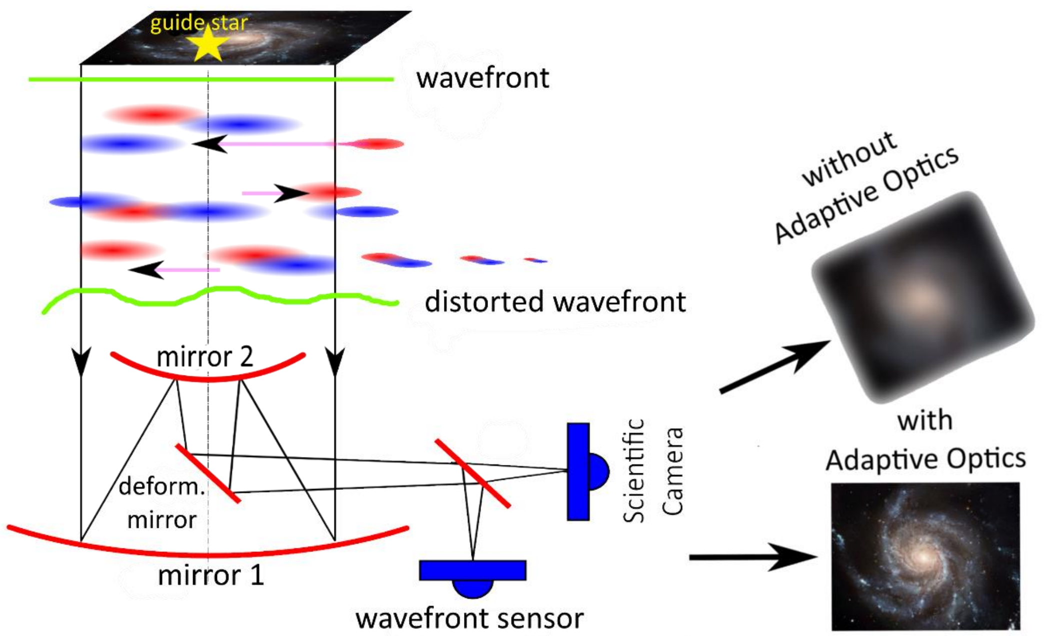
Astronomical imaging with ground-based telescopes suffers from quickly varying optical distortions in the atmosphere. Sharpness and contrast of these images are essential for astronomical observations, therefore, Adaptive Optics (AO) systems are applied. These systems are based on wavefront sensors, deformable mirrors and appropriate control algorithms.

CHALLENGES AND GOALS

Satisfying the demands on the AO system of the Extremely Large Telescope (ELT) of the European Southern Observatory is a challenging task. In real-time huge amounts of data have to be processed and thousands of actuators controlled by elaborated algorithms. Our project aims to develop and implement efficient control algorithms for the ELT first light-instrument MAORY.

MATHEMATICAL AND COMPUTATIONAL METHODS

In our project we developed and implemented an efficient real-time reconstruction algorithm for the ELT instrument MAORY on the high-performance hardware of the industrial partner. Our algorithm, called Finite Element Wavelet Hybrid Algorithm (FEWHA), is a conjugate gradient (CG) based solver for atmospheric tomography. FEWHA utilizes a dual-domain discretization strategy into a wavelet and finite element domain to obtain sparse operators. The matrix-free representation of these operators leads to a significant reduction in the computational load and memory resources. Moreover, the method is highly parallelizable. We use preconditioning and an augmented Krylov subspace method in order to reduce the number of CG iterations.



Basic design of an AO system

The incoming, distorted wavefront reaches the deformable mirror and gets corrected. A beam splitter splits the light into two parts. One part is propagated to the scientific camera and the other to the wavefront sensor. The already corrected sensor measurements are used by a control algorithm to compute the deformable mirror commands for the next incoming wavefront.

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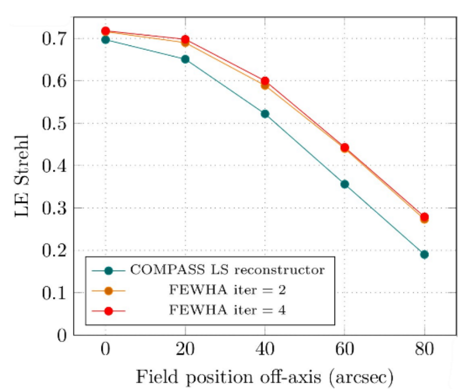
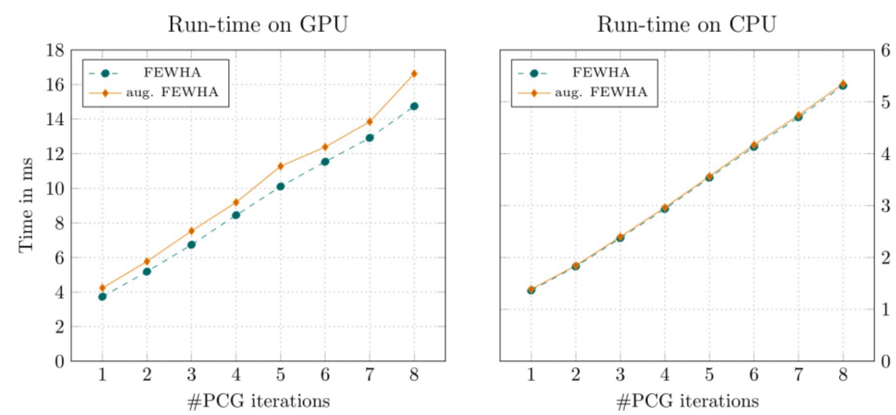
Results and Benefits

The main result of our project is an accurate and fast solver for atmospheric tomography optimized for the hardware of the industrial partner. The iterative real-time reconstructor FEWHA is running in real-time and provides an excellent reconstruction quality for the MAORY instrument. Microgate has benefited from the knowledge transfer on AO algorithms that can be used in further developments. Moreover, the company is able to extend its product portfolio and provide a package including efficient hardware and software for the real-time control of AO systems, not limited to astronomy applications.

An efficient
real-time reconstructor
for large AO systems
implemented and optimized
for Microgate's
AO control hardware



Quality verification.



Run-time analysis.

Digital Twin

IMNA - Industrial Mathematics Network for Austria

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