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# Herzberg Extensible Adaptive Real-time Toolkit (HEART) for ELT

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## Abstract

The Herzberg Extensible Adaptive Real-time Toolkit (HEART) is a collection of libraries and other software components developed at NRC-HAA that can be used to control different types of Adaptive Optics (AO) systems. HEART supports all flavours of AO, including Single Conjugate AO (SCAO), Multi-Conjugate AO (MCAO), Laser Tomography AO (LTAO), Ground Layer AO (GLAO) and Multi-Object AO (MOAO). The HEART RTC design has two main components: the Hard Real-Time RTC (HRT), which include all the time-critical high-speed processing tasks; and the Soft Real-Time RTC (SRT), which include the non-time critical tasks such as optimizations, AO parameter updates and diagnostics. The HRT and the SRT are connected via a private network.

The design of HEART took into consideration the rapidly advancing technology and uses commercial-off the shelf (COTS) CPUs running standard Linux distributions to using Matrix Vector Multiplication (MVM) reconstruct wavefront error coefficients from WFS measurements. Through extensive benchmarking, we have demonstrated that this approach meets the stringent latency and jitter requirements of modern AO systems. HEART is written in standard C and Python languages and can be readily customized to adapt to the specificities of any AO system, including specific Input/Output interfaces, or specific data processing flows and algorithms. In all cases however, the HRT processing is heavily parallelized and pipelined so that most of the processing is done as the pixels are streamed during the WFS camera read-out, resulting in a minimal latency between when the last pixel arrives and when the wavefront correction commands are ready to be written out.

HEART was originally designed for NFIRAOS, the first light AO System for the Thirty Meter Telescope (TMT). However, thanks to its modularity, it has been adapted to several new generation Gemini AO instruments, including the Gemini North AO (GNAO – LTAO/GLAO system) facility, the Gemini Planet Imager 2.0 (GPI 2.0 – high-order SCAO system) and the Gemini InfraRed Multi-Object Spectrograph (GIRMOS - MOAO system). HEART is also slated to be used for two major instruments for the European Extremely Large Telescope (ELT): MORFEO, formerly known as MAORY (MCAO system) and ANDES, formerly known as HIRES (SCAO system). This paper will delve into the unique design of the ANDES RTC and MORFEO RTC. In particular, we will discuss the specificities of these instruments requiring software customization, as well as the new challenges of operating in the ELT environment. Using HEART for two different ELT instruments will not only ensure excellent real-time performance for each of them, but will also guarantee higher robustness and easier maintenance for both of them.

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