The RTC receives an image from the WFS as input, executes computations in function of the or)

NCCR PlanetS TP-2018-SF6 project funding

In 2016, a rocky exoplanet has been discovered in the habitable zone of Proxima Centauri, the closest star from our solar system. This may represent our best current opportunity to search for life outside the Solar System.

The Observatory of Geneva has started a feasibility study for an instrument that would allow direct detection of Proxima Cen b in visible reflected light, and characterization of its atmosphere, by spatially resolving the planet to feed a high-resolution spectrograph. This instrument includes a powerful Adaptive Optics (AO) system to provide wavefront correction at visible wavelengths, capable to run at 4KHz in closed loop.

Adaptive Optics System Overview

The Adaptive Optics System is what corrects the blurring of the image due to the presence of the turbulent atmosphere between the light sources in the sky and the telescope on the ground.

AO Components
- WaveFront Sensor (WFS)
- Deformable Mirror (DM)
- Real-Time Computer (RTC)

Real-Time Computer

Functions
- Acquire the images from the WFS
- Pre-process the raw images
- Compute the wave front shape
- Compute the correction
- Send the command vector to the DM
- Control the system through Web Interface

Required Performance
- WFS Bandwidth < 1.4 Gb/s
- DM Bandwidth < 2.5 Gb/s

Estimated Resource Utilization

Hardware Unit | FP Unit | %
---|---|---
Preprocessing | TBC | TBC
Modal Decomposition | TBC | TBC
Optimal Control | TBC | TBC
Actuators Command | TBC | TBC

 Estimated Final Latency Time

Image Acquisition
Preprocessing
Modal Decomposition
Optimal Control
Actuators Command
Send the Command

Estimated Final Latency Time

<250us
<650us
<2us
<10us
<10us
<64us
<50us

Control Algorithm

The control algorithm is based on the concept of modes. These modes are the result of spatial decomposition of the shape of the wavefront into a set of functions orthogonal in the space of the pupil.

Preprocessing
Extract the slopes $s_1(x, y, k) = p_1(x, y) - p_2(x, y) - p_3(x, y) - p_4(x, y)$

Modal Decomposition
Compute the amplitude of the modes from the WFS signal $r(k) = D_k s(k)$

Optimal Controls
Apply IIR (Infinite Impulse Response Filter) using 36 coefficient for the first 5 modes

Actuators Command
Mapping the command to the mirror $v(k+1) = Mf(r(k+1))$

Target System Specifications

WaveFront Sensor
- OCA2K Camera
- 240x240@1500fps or 120x120@3700fps 14bit depth
- CameraLink Interface

Deformable Mirrors
- Boston Micromachine MEMS
- 500-4000 actuators

Real-Time Computer
- Up to 4KHz in closed loop
- Acquire images from WFS
- Compute the correction in less than 50µs
- Send the command vector to DM

Architecture
- Intel Arria10 SX660
- SoC: HPS+FPGA
- Hardened 32 bits floating point blocks (1600)
- 4Gib DDR4 64bit @1.2GHz FPGA mem
- 2Gib DDR4 32bit @1.2GHz HPS mem
- Dual-core ARM Cortex-A9
- Embedded Linux