ALPAO RTC

RTC4AO – 06/11/2023 – Bruno Martin
ALPAO and systems

- **ALPAO**:  
  - Deformable Mirror, Wave Front Sensors and RTC,  
  - 40 employees entirely dedicated to Adaptive Optic,

- **Our task**:  
  - Provide robust and compact real-time control solutions  
  - for astronomy and FSO  
  - up to 10kfps and 1k modes.
Outline

- ALPAO RTC overview,
- RTC interfaces,
- Inside the RTC,
- Test and performances,
- Implementation examples,
- Conclusion and perspectives
ALPAO RTC: Hardware & block Diagram

Configuration path

Real time path

User PC

Gbit Eth.

WFS

RTC

Gbit Eth.

DM

ALPAO – ADAPTIVE OPTICS – DEFORMABLE MIRRORS
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ALPAO RTC: Hardware & block Diagram

User PC

WFS

RTC

DM

Configuration path

Real time path

Gbit Eth.

Gbit Eth.
ALPAO RTC: User PC, Software interfaces & workflow

User PC

Matlab ACE Toolbox
- Fast learning / Fast prototyping,
- GUI,
- Large code base.

C/C++ RTC SDK
- Minimal dependencies
- Industrial environment operation

Gbit Eth.

WFS

RTC

DM

Gbit Eth.

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ALPAO RTC: User PC, Software interfaces & workflow

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WFS

RTC

Gbit Eth.

DM

WFS

RTC

Gbit Eth.

DM
ALPAO RTC: RTC & parallel processes

- Configure RT application.
ALPAO RTC: RTC & parallel processes

- Configure RT application.

RTC

HKL

Input

Worker 1

Worker 2

Worker N

Sink Filter and Output

User PC

1. Controls camera,
2. Applies bias image,
3. Acquires images,
4. Distributes part of images to workers,
5. Writes image in buffer.

WFS

DM

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ALPAO RTC: RTC & parallel processes

- Configure RT application.

RTC

HKL

Worker 1

Worker 2

Worker

Worker N

Sink Filter and Output

User PC

Input

- Controls camera,
- Applies bias image,
- Acquires images,
- Distributes part of images to workers,
- Writes image in buffer.

- Compute CoG on parts of images,
- Apply reference and target slope,
- Compute MVM parts,
- Parallel processes,
- Write slope in buffer.

WFS

DM

KHK

GigE Vision

Camera Link

- Controls camera,
- Applies bias image,
- Acquires images,
- Distributes part of images to workers,
- Writes image in buffer.
ALPAO RTC: RTC & parallel processes

- Configure RT application.

**RTC**

- Controls camera,
  - Applies bias image,
  - Acquires images,
  - Distributes part of images to workers,
  - Writes image in buffer.

- Compute CoG on parts of images,
  - Apply reference and target slope,
  - Compute MVM parts,
  - Parallel processes,
  - Write slope in buffer.

- Aggregates MVM results parts,
  - Applies integrator and AO loop gain,
  - Encodes command and
  - Sends command to DM,
  - Writes command in buffer.

**WFS**

**DM**

**HKL**

**User PC**

**Worker 1**

**Worker 2**

**Worker N**

**Sink Filter and Output**
ALPAO RTC: RTC & parallel processes

- Configure RT application.

HKL

Input

Worker 1

Worker 2

Worker N

Sink Filter and Output

- Many Inputs.
- Workers content can be adapted.
- Many outputs.

RTC

User PC

WFS

DM

ALPAO – ADAPTIVE OPTICS – DEFORMABLE MIRRORS
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ALPAO RTC: RTC & parallel processes

- Configure RT application.
- Share telemetry.

Input

Worker 1
Worker 2
Worker
Worker N

Sink Filter and Output

HKL

User PC

Share

- Many Inputs.
- Workers content can be adapted.
- Many outputs.
ALPAO RTC: RTC & parallel processes

- Configure RT application.
- Share telemetry

Input
Worker 1
Worker 2
Worker N
Sink Filter and Output

- Many Inputs.
- Workers content can be adapted.
- Many outputs.

User PC

HKL

Share

WFS
DM

- Configure RT application.
- Share telemetry
ALPAO RTC: RTC & HDF5 & share

Share: HDF5 files for Telemetry data (image, slope and commands),
- Many languages supported (Matlab, C/C++, java, python, ...),
- Self describing,
- Each process writes in its circular HDF5 buffer in SWMR mode,
- idx_last_write attribute let a reader know where last data has been written.

Write cursor
Read cursor

e.g. OCAM2K 16x16 s.a. + DM292 @2kHz : recording @~230MB/s
ALPAO RTC: Performance test setup

- **WFS**: 256x256 pixels, 32x32 sub-apertures, @5kHz
- **RTC**: NI USB 6343 Time stamper
  - CH1: end of exposure time
  - CH2: start of AMPI card reception
- **DM820**: 820 actuators
- **Gbit Eth.**

Connections:
- CH1 from WFS to RTC
- CH2 from RTC to DM820
- Pulsed connections from RTC to WFS and from RTC to DM820
ALPAO RTC: Performance test setup

NI USB 6343
Time stamper

CH1: end of exposure time
CH2: start of AMPI card reception

Pulses

WFS
256x256 pixels
32x32 sa
@5kHz

Pixel transfer: 195μs

RTC latency: 65μs

Pulses

DM820
820 actuators
ALPAO RTC: Performance test results

- Long run: 12h, Real time,
- DM820, 32x32 sa,
  RTC Latency:
  - Average: ~65µs
  - std. dev.: ~1.5us
  - Max: ~95µs

![Graph showing RTC latency results]
ALPAO RTC: Performance test results

- Long run: 12h, Real time,
- DM820, 32x32 sa, RTC Latency:
  - Average: ~65\mu s
  - std. dev.: ~1.5\mu s
  - Max: ~95\mu s
- DM468, 24x24 sa:
  - Frame rate: 8kHz
  - RTC Latency: ~40\mu s
- DM292, 20x20 sa:
  - Frame rate: 10kHz
  - RTC Latency: ~33\mu s
ALPAO RTC implementations: LGS AO System

LGS Downlink

DM277

WFS @2kHz

RTC

WFS TT @60Hz

LGS Uplink

FSM

JLM

Leading the light
ALPAO RTC implementations: LGS AO System

ALPAO RTC architecture for Multiple Inputs, Multiple Outputs

LGS Downlink

- DM277
- WFS @2kHz
- WFS TT @60Hz
- RTC

JLM
ALPAO RTC implementations: PyWFS on PAPYRUS OHP

- Project in collaboration with LAM team
- 80x80 pixel for Pyramid pupil, DM241,
- Up to 2kHz,
- RTC latency less than 150µs.
ALPAO RTC implementations: PyWFS on PAPYRUS OHP

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Conclusions et perspectives

- **Conclusions:**
  - ALPAO RTC architecture and features,
  - Stability, determinism and performances of the solution,

- **Perspectives:**
  - ALPAO is partner in 2 projects: COOP and TeQuants pave the road for industrial FSO-AO,
  - Fast DM control,
  - Operational RTC automation,
  - Telemetry server for fast recording.
Thanks

www.alpao.com