WFS Arbitrator interface

Prepared by: A. Puglisi

Approved by:

Released by:
ABSTRACT

This document describe the software interface for the WFS arbitrator of the First-light AO units. The interface is identical for right and left units.
# Modification Record

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<th>Version</th>
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<tr>
<td>1.0</td>
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<td></td>
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</tr>
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### Abbreviations, acronyms and symbols

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>LBT</td>
<td>Large Binocular Telescope</td>
</tr>
<tr>
<td>WFS</td>
<td>WaveFront Sensing unit of the LBT AO system</td>
</tr>
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1. Introduction

The WfsArbitrator is the main control program for the WFS system. It is based on a finite state machine model of the WFS operation, with some additional features for specific AO and engineering operations.

WfsArbitrator is an AOApp (see ...) which integrates in the AO Supervisor system. It is a server which waits for commands from the higher-level AO Arbitrator, or from other parties (e.g. GUIs or calibration interfaces). Commands are exported using the common arblib framework (see ...). All commands return a completion code which indicates whether the requested operation has been successfully executed.

2. Integration in the AO system

The WfsArbitrator manages the WFS part of the first light AO system. As such, its operation is coordinated by the higher-level AO arbitrator. The WfsArbitrator does not distinguish between service states as Observation and Engineering like the AO arbitrator. Instead, the software interface is fully available at all times, and the different observing modes are handled by the AO arbitrator.

The Engineering Interface completely bypasses the WfsArbitrator and talks instead with the hardware. Therefore, when the WfsArbitrator is operating no commands must be sent from the Engineering Interface (which can remain as a read-only status information). The WfsArbitrator provides some special commands to allow limited manual control of devices, but these commands are intended to be used only in engineering mode and not during observation.

3. FSM design

The following is the FSM model of the WfsArbitrator. Most commands are implemented as transitions between states.

In general, there are three completion codes for a state transition:

- **SUCCESS**: the command was executed successfully
- **ERROR**: the command cannot be executed because of an internal WFS failure (e.g. hardware failure)
- RETRY: the command cannot be executed now because of an external error (e.g. no light on sensor) and can be tried again if needed.

Commands ending in SUCCESS leave the WFS in the target state. In case of RETRY the WFS is rollbacked to the previous state (therefore no state transition occurs), while ERROR leave the WFS in Failure state and a RecoverError command must be issued.

Each command may add more detailed status information to the completion codes described above.

4. State change commands

Most commands are implemented as transitions between WfsArbitrator states.

4.1. Operate

This command put the WFS hardware into an operating state and checks all needed functionality. This is the first command to use after power on, and can be used to “reset” the WFS system to a known state.

Valid states: Off, PowerOff, AOPrepared, AOSet, Operating, Stop, RecoverableError
End state: Operating
Return values: Status code.
Time needed: about 2 minutes for full system.
Parameters:

<table>
<thead>
<tr>
<th>Name</th>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Config</td>
<td>String</td>
<td>Requested configuration (from a list provided by the WFS arbitrator). A null value default to full WFS system.</td>
</tr>
</tbody>
</table>

4.2. Off

This command turns safely off all the WFS hardware. Intended as normal power off procedure.

Valid states: Operating
End state: Off
Return values: Completion code.
Time needed: 20 seconds.
Parameters: None

4.3. PrepareAcquireRef

This command prepares the WFS to reference star acquisition. All filters are selected, stages are moved to the expected star position and CCDs are started at the expected frame rate. This command can be sent before the telescope has pointed or tracked the scientific object, to minimize the star acquisition overhead.

The result of this code is a description of the WFS parameters that will be used for the star acquisition and closed loop, as they were selected by the software. It is possible to override some of this parameters with the RefineAO command before closing the loop.

Valid states: Operating, AOPrepared, AOSet
End state: AOPrepared

Return values: Completion code plus parameters (see below)

Time needed: up to 2 minutes.

Parameters:

<table>
<thead>
<tr>
<th>Name</th>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>AOMode</td>
<td>String</td>
<td>Requested AO mode. Either “TT” or “AO” for tip-tilt only or full AO correction</td>
</tr>
<tr>
<td>SOCoords</td>
<td>float[2]</td>
<td>Expected scientific object position in focal plane mm from the telescope FOV center</td>
</tr>
<tr>
<td>ROCoords</td>
<td>float[2]</td>
<td>Expected reference star position in focal plane mm from the telescope FOV center.</td>
</tr>
<tr>
<td>Elevation</td>
<td>Float</td>
<td>Expected telescope elevation when tracking will start.</td>
</tr>
<tr>
<td>RotAngle</td>
<td>Float</td>
<td>Expected telescope rotator angle when tracking will start.</td>
</tr>
<tr>
<td>GravAngle</td>
<td>Float</td>
<td>Expected telescope rotator angle when tracking will start, with respect to gravity.</td>
</tr>
<tr>
<td>Mag</td>
<td>Float</td>
<td>Reference star magnitude.</td>
</tr>
<tr>
<td>Color</td>
<td>Float</td>
<td>Reference star B-V color index.</td>
</tr>
</tbody>
</table>

Output parameters:

<table>
<thead>
<tr>
<th>Name</th>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>CompStatus</td>
<td>String</td>
<td>Completion status</td>
</tr>
<tr>
<td>DeltaXY</td>
<td>float[2]</td>
<td>Stages position in FoV coordinates from telescope FoV.</td>
</tr>
<tr>
<td>nModes</td>
<td>Int</td>
<td>Number of modes that will be corrected. Always 2 for TT mode, more for AO correction</td>
</tr>
<tr>
<td>Itime</td>
<td>Float</td>
<td>Integration time that will be used for the AO loop, in seconds.</td>
</tr>
<tr>
<td>Bin</td>
<td>Int</td>
<td>Binning that will be used for the AO loop.</td>
</tr>
<tr>
<td>Ttmod</td>
<td>Float</td>
<td>Internal tip-tilt modulation radius that will be used for the AO loop, in radians.</td>
</tr>
<tr>
<td>Fw1Pos</td>
<td>String</td>
<td>Selected filter for filter wheel #1</td>
</tr>
<tr>
<td>Fw2Pos</td>
<td>String</td>
<td>Selected filter for filter wheel #2</td>
</tr>
<tr>
<td>Gain</td>
<td>Float</td>
<td>Loop gain</td>
</tr>
</tbody>
</table>

### 4.4. AcquireRef

This command starts the guide star acquisition (previously prepared by the PrepareAcquireRef command). It is assumed that the telescope is pointing and tracking the scientific object.

Valid states: AOPrepared, AOSet
End state: AOSet
Return values: Completion code plus parameters (see below)
Time needed: about 1 minute
Parameters: None
Output parameters:

<table>
<thead>
<tr>
<th>Name</th>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ROCoords</td>
<td>float[2]</td>
<td>Reference star position in focal plane mm from the telescope FOV center.</td>
</tr>
<tr>
<td>Mag</td>
<td>Float</td>
<td>Estimated reference star magnitude.</td>
</tr>
</tbody>
</table>

4.5. RefineAO

This command can modify the automatic parameters chosen for the loop. Can be used in AOSet mode before closing the loop.

Valid states: AOSet
End state: AOSet
Return values: Completion code
Time needed: usually 10 seconds. Up to 1 minute if the binning is changed.
Parameters:

<table>
<thead>
<tr>
<th>Name</th>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Itime</td>
<td>Float</td>
<td>Integration time that will be used for the AO loop, in seconds.</td>
</tr>
<tr>
<td>Bin</td>
<td>Int</td>
<td>Binning that will be used for the AO loop.</td>
</tr>
<tr>
<td>TTmod</td>
<td>Float</td>
<td>Internal tip-tilt modulation radius that will be used for the AO loop, in radians.</td>
</tr>
<tr>
<td>Fw1Pos</td>
<td>String</td>
<td>Selected filter for filter wheel #1</td>
</tr>
<tr>
<td>Fw2Pos</td>
<td>String</td>
<td>Selected filter for filter wheel #2</td>
</tr>
</tbody>
</table>

4.6. CloseLoop

Closes the loop using the current parameters. AdSec is assumed to be in state RunningAO. Time needed is 5 seconds. This command just enables the fastlink fiber.

Valid states: AOSet
End state: LoopClosed
Return values: Completion code
Time needed: 5 seconds.
Parameters: None

### 4.7. RefineLoop

This command allows to change some loop parameters on the fly, keeping the loop closed. Time is 5 seconds.

Valid states: LoopClosed
End state: LoopClosed
Return values: Completion code
Time needed: 5 seconds
Parameters:

<table>
<thead>
<tr>
<th>Name</th>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>itime</td>
<td>Float</td>
<td>Integration time that will be used for the AO loop, in seconds.</td>
</tr>
<tr>
<td>TTmod</td>
<td>Float</td>
<td>Internal tip-tilt modulation radius that will be used for the AO loop, in radians.</td>
</tr>
<tr>
<td>Fw2Pos</td>
<td>String</td>
<td>Selected filter for filter wheel #2</td>
</tr>
</tbody>
</table>

### 4.8. CorrectModes

This command a modal correction can be applied by the WFS during closed loop. In its most general form, the modes will be corrected by modifying the reference slope vector used by the WFS, therefore generating an offset signal that will drive the AdSec to the correct shape. This command can modify the automatic parameters chosen for the loop. Can be used in SetAO mode before closing the loop.

Valid states: LoopClosed
End state: LoopClosed
Return values: Completion code
Time needed: 5 seconds
Parameters:

<table>
<thead>
<tr>
<th>Name</th>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modes</td>
<td>float[64]</td>
<td>Vector of Zernike coefficients to correct. Amplitude in meters.</td>
</tr>
</tbody>
</table>

### 4.9. OffsetXY

Requests an XY correction by moving the WFS stages. Only possible during closed loop.

Valid states: LoopClosed
End state: LoopClosed
Return values: Completion code
Time needed: 5 seconds
Parameters:
4.10. **OffsetZ**

Requests a Z (focus) correction moving the WFS stages. Only possible during closed loop.

- **Valid states:** LoopClosed
- **End state:** LoopClosed
- **Return values:** Completion code
- **Time needed:** 5 seconds
- **Parameters:**

<table>
<thead>
<tr>
<th>Name</th>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Offset</td>
<td>float[2]</td>
<td>Requested offset in FoV coordinates (mm).</td>
</tr>
</tbody>
</table>

4.11. **PauseLoop**

Pauses the closed loop, stopping the slope data towards the secondary mirror. Time is 5 seconds. The loop can be resumed at any time.

- **Valid states:** LoopClosed
- **End state:** LoopPaused
- **Return values:** Completion code
- **Time needed:** 5 seconds
- **Parameters:** None

4.12. **ResumeLoop**

Resumes a previously paused closed loop, without re-acquiring the reference star. The resume operation can fail if in the meantime tracking has drifted too far (>1 arcsec) and there is no light anymore on the WFS. Time is 5 seconds.

- **Valid states:** LoopPaused
- **End state:** LoopClosed
- **Return values:** Completion code
- **Time needed:** 5 seconds
- **Parameters:** None

4.13. **StopLoop**

Stops a closed loop. The loop cannot be resumed and an additional PrepareAcquireRef command must be used.

- **Valid states:** LoopClosed, LoopPaused
- **End state:** Operating
4.14. **RecoverFailure**

Tries to recover from a previous failed command. Final state will be Operating if the recovering is successful. Highly dependent on the kind of failure happened.

- Valid states: Failure
- End state: Operating
- Return values: Completion code
- Time needed: varies.
- Parameters: None

4.15. **EmergencyOff**

Shut down immediately the WFS for safety reasons. Any operation in progress will be aborted. Can be sent asynchronously while another command is executing.

- Valid states: Any
- End state: Off.
- Return values: Completion code
- Time needed: 1 second.
- Parameters: None

4.16. **GetTVimage**

Gets the current Technical viewer image as a binary string.

- Valid states: Any
- Return values: Completion code plus parameters (see below)
- Time needed: 5 seconds.
- Parameters: None
- Output parameters:

<table>
<thead>
<tr>
<th>Name</th>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Image</td>
<td>String</td>
<td>Binary representation of the image in a TCS-accepted format.</td>
</tr>
</tbody>
</table>
5. Calibration

5.1. WFS-only calibrations

Some calibrations are specific to the WFS system only. The WfsArbitrator provides commands to perform such calibration. Such commands can be sent by the higher level AO arbitrator or by an operator. All calibration commands are accepted when in Operating state. Results are saved in disk files on the AO workstation as lookuptables and reference frames, that will be automatically referenced during operation. Calibrations are grouped into

5.1.1. SetSource

Command to select either the reference source or the telescope beam. A source must be specified before any calibration operation. This command is also used to change the intensity of the calibration source to a different value.

Valid states: Operating
End state: Operating
Return values: Completion code
Time needed: 1 minute.
Parameters: None

Parameters:

<table>
<thead>
<tr>
<th>Name</th>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Config</td>
<td>String</td>
<td>Requested source (either “CALIBRATION” or “TELESCOPE”)</td>
</tr>
<tr>
<td>Magnitude</td>
<td>Float</td>
<td>Equivalent magnitude for the calibration source.</td>
</tr>
</tbody>
</table>

5.1.2. CalibrateDarkFrames

Calibrates dark frames for the WFS ccds. The system must be in the dark with no light coming from any source.

Valid states: Operating
End state: Operating
Return values: Completion code
Time needed: 1 minute.
Parameters: None

5.1.3. CalibrateMovements

Calibrates stages, filterwheel and tip-tilt movements with optical feedback.

Valid states: Operating
End state: Operating
Return values: Completion code
Time needed: 5 minutes.
Parameters: None
5.1.4. **CalibratePupils**
Calibrates pupil position on the ccd39.

Valid states: Operating
End state: Operating
Return values: Completion code
Time needed: 1 minute.
Parameters: None

5.1.5. **CalibrateSlopenull**
Calibrates the reference slope vector. Assumes a flat Adaptive Secondary.

Valid states: Operating
End state: Operating
Return values: Completion code
Time needed: 1 minute.
Parameters: None

5.2. **AO system calibration**
Some calibrations (e.g. acquiring the interaction matrix) require interaction between the WFS and the Adaptive Secondary. Such calibrations will therefore be coordinated by the AO arbitrator. The WfsArbitrator must be in Operating state for such calibrations.

6. **Variables**
The WfsArbitrator assumes that a few variables from the DD are made available by the AOS and kept regularly updated. The following is a list of such variables:

<table>
<thead>
<tr>
<th>Name</th>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>TelPointingEqu</td>
<td>Float</td>
<td>Current pointing coordinates, AR and DEC</td>
</tr>
<tr>
<td>TelPointingAlt</td>
<td>Float</td>
<td>Current pointing coordinates, Az. and El.</td>
</tr>
<tr>
<td>RotatorPos</td>
<td>Float</td>
<td>Current rotator position</td>
</tr>
</tbody>
</table>
7. References

