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ACTIVE OPTICS CONTROL SYSTEM FOR THE GALILEO TELESCOPE. A STATUS REPORT

[1]F. Bortoletto, [1]D. Fantinel, [3]W. Gallieni, [2]G. Giudici,
[1]R. Ragazzoni, [3]R. Tommelleri, [2]P. Vanini
[1]TNG project, Astronomical Observatory of Padova
[2]SOFTEAM, via f.lli Cairoli 59, 22053 Lecco (CO)
[3]ADS, via ai Poggi 58B, 22053 Lecco (CO), Italy

Abstract

The Italian Galileo telescope (TNG) is a 3.6 meters instrument with ALT-AZ mounting providing two Nasmith focal stations and to be operated in La Palma (Canary islands); the status report of the Active Optic subsystem is briefly described.

1. Introduction

The active optics scheme of TNG allows, like for others telescopes of the new generation (NTT, JLNT, VLT), compensation of a wide series of errors with direct effect on the optical performance; errors can be of different kind ranging from pure optical misadjustment up to low frequency tracking instabilities.

TNG optics is designed in a way optical errors can be detected, analyzed and decomposed in modal form (distortion terms) allowing further correction on term by term basis.

Only first distortion terms can be actively corrected directly acting on the optics being higher terms dependent on the optical quality of mirrors and/or atmospherical (seeing) conditions.

TNG can correct focus and third order coma acting on the secondary mirror position, while the other terms, with the exception of tilt, are corrected by elastic deformation of the primary mirror.

Unlike the NTT case, where the tilt term can be corrected only acting on the main drive system, TNG allows also correction of tilt by means of the tertiary mirror.

Generally speaking the overall active optics is a feedback based control system where, step by step, the optical wavefront error is detected through wavefront analisys, the error information is decomposed in independent terms, the amount of action is computed from precalibrated tables and the action is eventually taken.

The resulting control system, from the informatic viewpoint, requires an high number of microcontrollers able both to work in parallel and to interact between them at some moderate distance.

2. The M1 system

The primary mirror (M1) is supported by a set of 75 axial active supports based on astatic levers, so the required modal elastic deformation of the mirror is obtained through variation of the overall pattern of forces applied by the supports[1,2]; three extra axial supports plus a number of radial support are used for monitoring and for passive balancing of the mirror.

In practice each support must be driven in order to precisely react applying the required force to the mirror contact point (±100 grams on a overall range of 100 kilograms).

Such task is obtained by a servo-loop closed inside the actuator itself in two basic steps (i) reading the information from a load-cell interposed between the mirror and actuator; and (ii) acting on a counter-weight lever arm driven via a motor-tachometer couple.

3. The M2 system.

Unlike the NTT case where the secondary mirror (M2) driving system is mechanically designed in order to allow only the kind of movement needed to correct defocussing and/or third order coma, the TNG system allows virtually any kind of positioning of M2 in the space; so the proper motion must be obtained by means of an intelligent controller plus a cinematic model of the M2 mechanics.

The scope of this variant is to have a system virtually free of back-lash effects and fully parametrizable. The way the mirror is hang-up and positioned is by means of two platforms mutually interconnected with six elongation-controlled bars; platforms are connected one to the telescope (M2 spider) and one to the M2 holder respectively.

Each bar can be positioned (elongated) with a local control-loop made by motor, spindle, tachometer and encoder.

4. The M3 system.

Usually the control of tilt is performed in different ways, like with the help of the main drive system (autoguiders) or with the help of a small and fast tiltable mirror somewhere on the optical path. The first system provides small bandwidth (usually some fraction of Hz) and requires an intervent on the overall telescope structure to get the wanted correction with the possibility to excitate the proper resonant frequency of the overall telescope structure; it is part of TNG control system and must be used to correct long term tracking drifts.

Tilt correction with a dedicated mirror[5] provides high bandwidth (about 20 Hz and even more) but requires dedicated optics and mechanics; the TNG solution is to use the already present tertiary mirror (M3) and to reserve fast correction (even full adaptive optics if possible) to an external module when available[6].

M3 is tilted in two orthogonal axes allowing an accuracy of 0.1 arcsec and a dynamic of ≈ 4 arcsec on the focal plane; the movement is obtained by three preloaded piezo stacks closed in loop with two LVDT sensors.

A dynamical modellization of the full M3 system plus support spiders shown the possibility to drive this mirror up to 10 Hz without any noticeable effect on the telescope structure.

The external control system must insert the required tilt and monitor the obtained position.

5. Control scheme for TNG optics

The overall correction of the optical figure (including here also the autoguider system) starts from the analysis of the optical wavefront at the focal plane (Shack-Hartmann camera analyzer) plus detection of the tracking-tilt error via normal TV camera. Further decomposition of error in linear-independent terms is obtained via computer algorithm, while final estimation of the pattern of forces to apply (M1 case), amount and kind of movement to apply (M2 and M3 cases) is obtained via precalibration tables based on elastic model (M1 case) or kinematic model (M2 and M3).

The bandwidth involved in the different kind of corrections is:

- 0.1 - 0.001 Hz for the M1 and M2 case
- 10 Hz for the M3 case
- 0.3 Hz for the telescope autoguider

THe lowest bandwidth is concerned with M1-M2 where it is necessary to integrate the reference star providing light for the wavefront analyzer enough time (some tens of seconds) to integrate fast distortion due to atmospheric seeing.

Each actuator, the total number is 83 (75 on M1, 6 on M2 and 2 on M3), must provide the following two functions (or at least, m3 case, the second of them): (i) velocity loop, the inner loop closed between motor and on-axis tachometer; and (ii) position loop: the outer loop where position (or force) is sensed and held. Although control loops are all identical from the point of view of basic functions performed, it should be noted that there can be two basic differences, one is related with the error measurement which can be obtained from direct sensing (*i.e.* encoders, LVDT, etc.) or from more complex operations via Shack Hartmann (SH) analysis, the second is concerned with the rate of actuation.

6. The transputer network

There is a number of recent technological developments concerned with astronomy based on transputer arrays. For instance on the field of detector controllers[3] and on the field of telescope and instrumentation control[4].

There are two common advantages pointed out in such a choice:

1. the possibility to have concurrent processing at the level of a single node and to spread on multiple nodes;
2. the possibility to have a mechanism of fast intercommunication based on four interconnectable serial links per node.

It is to be noted that the above two mechanisms are completely embedded inside the hardware architecture of the transputer chip and are under the direct control of the transputer development language (OCCAM). This means that the amount of external hardware for a complex array of nodes is minimum (even no hardware at all for short distances, about 30 cm) and there is no need of software drivers and special handling of concurrent communications.

7. The motor-controller board

In order to simplify the hardware needed for each node a basic transputer board to be customized for specific control functions has been developed.

The transputer is a T425 16bit chip with 4 serial links working at the maximum speed of 20 Mbit/sec. On a single-size board there are the following built-in functions:

- 4 analog to digital 12 bit channels;

- 4 digital to analog 8 bit channels;
- a read-only preselectable 8 bit dip-switch;
- two 8 bits input-output ports.

All the above inputs and outputs are available on a 32 pins edge connector so the node-board can be customized inserting an extra board with the specific node hardware.

The node-board is of standard single-size and can be connected to a simple back-plane carrying only power-supply and the transputer communication lines (four bidirectional links plus three common service lines).

One of the four links is carried to a size-two transputer-module slot made on the node-board itself so, should the node-board to be operated at large distance, it is possible to communicate via a fiber-optic link adapter mounted in piggy-back.

The load-cell is connected to one A/D input through a signal conditioner (Analog Dev. 1B31) which provides also the bias voltage. The resolution achieved is of the order of 30 grams with a Philips PR6206/22M1 cell.

The motor speed loop is obtained via an op. amp. based circuit, so, in the M1 application, the transputer is concerned only with the handling of the required support force (*position* loop).

8. Conclusions

A prototype of board based on a 16bit transputer processor has been developed and checked. The board can be configured, with minor modifications, as a controller for several kinds of actuator systems based on closed loop feedback. This board can be part (node) of a network of similar devices matching a particular control operation; this possibility is assured by four serial links extendable to medium distance through optical fibres. The handling of every kind of configuration is assured by a software routing protocol mounted on the master node and down-loaded at start-up.

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