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Telescope guide and pointing precision at THEMIS(*)

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Summary. — We present the very basic features—from the observer's point of view—of the software pack allowing for driving the telescope, the dome, the preslit at the primary focus and the field rotator between the primary and the secondary focus. The original program was developed by C. Veillet as an adaptation for THEMIS of the program used to drive the "Laser-Lune" telescope at the Observatoire of the Côte d'Azur (France). Further adaptations were made by the authors to meet observational and technical needs emerged during operation of the THEMIS telescope. When talking about the way observations at THEMIS are affected by the pointing precision we clearly have to distinguish between to different levels: 1) a short-term effect, affecting short-term observing actions such as scans on the solar disk and 2) a long-term level affecting the correct tracking of a target. All short-term effects just depend on the precision of the software interface and we discuss here their origin, the way they are controlled, their value and how they affect scanning procedures. All long-term effects depend on precision of the software interface but also on mechanical and optical alignment accuracy.

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PACS 96.60.-j – Solar physics.
PACS 01.30.Cc – Conference proceedings.

1. – Pointing axes and telescope guide software interface

We refer to the THEMIS pointing axes as to the 6 degrees of freedom allowing for the focal point F1 to receive the image of a desired target: 1) telescope elevation angle, 2) telescope azimuth angle, 3) field-rotator angle, 4) Preslit angle, 5) dome azimuth angle and 6) dome pseudo-elevation angle.

As illustrated in fig. 1, three servo-systems are dedicated to the pointing axes driving:

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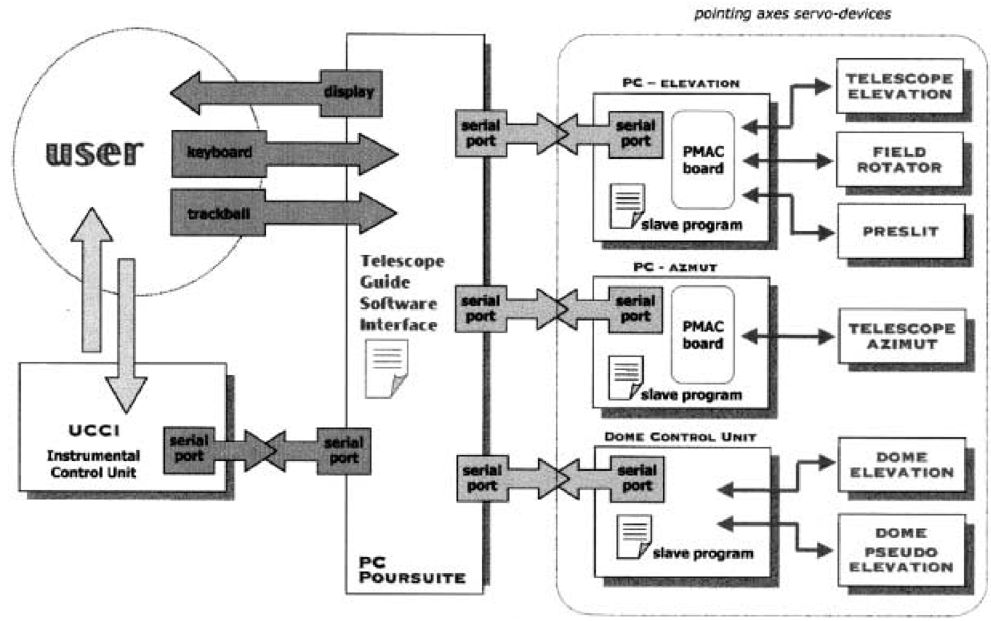

Fig. 1. – Block scheme of the control of the pointing axes.

a) pointing axes 1, 3 and 5 are controlled by a dedicated PC via a P-MAC board and a dedicated software;

b) pointing axis 2 is controlled by a dedicated PC via a P-MAC board and a dedicated software;

c) pointing axes 5 and 6 are controlled by a special unit supplied along with the dome by the manifacturing company.

All the three servo-systems listed above run in slave mode, each one to be accessed via a serial port to input the command string according with the fixed protocol.

A dedicated PC is used to interface the observer to the three servo-systems described above:

a) on the servo-system side it is equipped with three serial ports—one for each servo-system;

b) on the observer's side, it can be accessed either via keyboard/trackball or via a serial port through a further interface chain whose last step is to be the Instrumental Control Unit (UCCI);

c) the full software pack interfacing the observer's side to the servo-systems side is referred to as Telescope Guide Software Interface—herehence TGSI.

2. – User level software architecture

The TGSI is accessible at three different levels:

a) at *Level* 0 the pointing axes are not moving and no direct driving of them is allowed; the Supervisor Mode Software Interface allows for

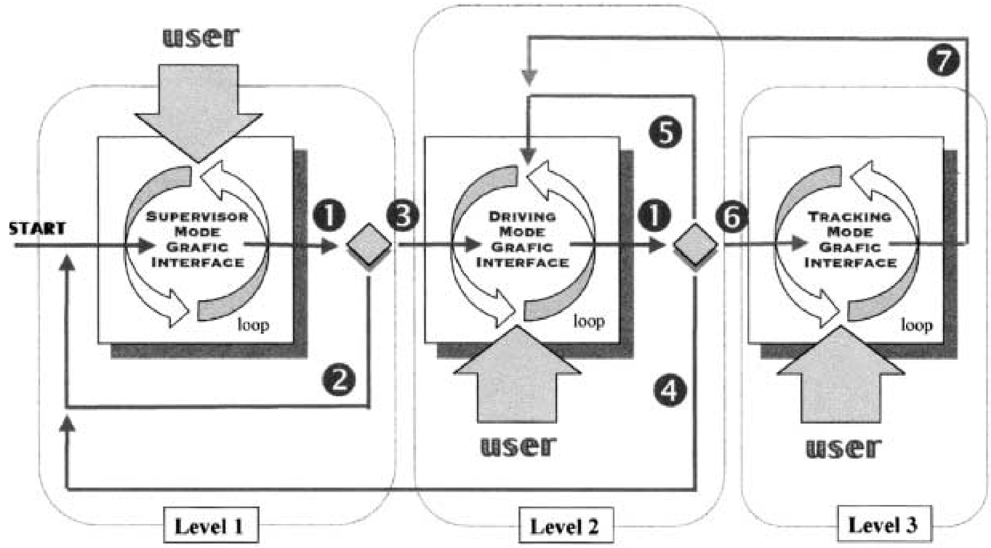

Fig. 2. – User level scheme of the software architecture. See text for details.

1) running off-line operations like the update of targets coordinate and GPS time reference or preparation of the sky mapping procedure;

2) access *Level* 1 for technical and set-up purposes such as telescope initialization and special positionings;

3) access *Level* 1 for observational purposes;

b) if *Level* 1 is accessed for observational purposes the pointing axes are in a stand-by status and the Driving Mode Software Interface will allow for direct driving of them;

c) at *Level* 2 the pointing axes are tracking coordinates according with the options chosen at *Level* 1; the Tracking Mode Software Interface allows:

1) real-time screen monitoring of pointing axes information;

2) real-time recovering of pointing axes information through serial port comunication;

3) on-line tracking actions, through keyboard, trackball and serial port comunication—see sect. **4**.

In the case of serial port comunication full procedures can be prepared and performed so far.

The user level scheme of software architecture is as follows (see also fig. 2, each item referring to a block of this figure):

1) When the Grafic Interface receives a user request—via keyboard, trackball or serial port—it soon converts it into a corresponding external request to be passed to the main program via a text file; the Grafic Interface is then terminated and the control is passed to the main program for the external request to be handled.

2) The detected external request is not for moving on to Level 1: an internal function of the main program—user interactive or not—corresponding to the detected request is executed; when the function is terminated the Supervisor Mode Graphic Interface is restarted.

3) The detected external request is for moving on to Level 1: the Driving Mode Graphic Interface is started.

4) The detected external request is for moving back to Level 0: the Supervisor Mode Graphic Interface is started.

5) The detected external request is not for moving on to Level 2: an internal function of the main program—user interactive or not—corresponding to the detected request is executed; when the function is terminated the Driving Mode Graphic Interface is restarted.

6) The detected external request is for moving on to Level 2: the Tracking Mode Graphic Interface is started.

7) The Tracking Mode Graphic Interface may receive a user request via keyboard, trackball or serial port for moving back to Level 1.

3. – Target coordinates and open-loop tracking

The pointing axes control works in an *open loop mode* as explained below.

The TGSI is equipped with a data file containing all the necessary information to compute—at any wanted time during the current year—the absolute equatorial coordinates of 9 available targets (8 solar system planets and the solar disk center); such file is constructed starting from the JPL Lunar and Planetary Ephemerides DE405 [1] ([1]). Anytime the TGSI is started a table is constructed for each solar system target, containing the target equatorial coordinates computed for the following 12 hours at intervals of 30 minutes.

When tracking on a peculiar target, the following actions are taken at regular time steps of 100 ms (the GPS device is used as absolute time reference):

a) computation of the time at which the telescope pointing axes servo-systems (elevation, azimuth, preslit and field rotator) are supposed to be processing the positioning command to be sent at current step—the *time delay* necessary for the telescope to perform its movement is taken into account.

b) Computation of the target equatorial coordinates—taking into account all the observer's options—for the time defined above by interpolation of the table described above.

c) Computation of the corresponding pointing axes coordinates—preslit angle is computed to preserve the selected orientation.

d) Output of the positioning command to the pointing axes servo-systems—the dome is positioned as a consequence of the telescope alt-azimuthal position.

e) Readout of the position the pointing axes had at the time the last positioning command was processed.

The *pointing errors* due to the software interface is the difference—at any time—between the actual readout position and the one requested for that time.

([1]) www.willbell.com

4. – On-line tracking actions

On-line tracking actions are allowed by the Tracking Mode Software Interface. This includes the possibility for

a) modifying the field-rotator angle—that is at every pointing step the selected increment is added to the should-be angle.

b) Changing the preslit orientation to be preserved during the tracking and/or modifying the prreslit angle with respect to the selected orientation—that is at every pointing step the selected increment is added to the preslit angle corresponding to the selected orientation.

c) Displacing the pointing target all over the solar disk along different coordinate systems: heliographic, polar, equatorial.

d) Displacing the pointing target in alt-azimuthal coordinates is also possible but only via serial port instructions; in this case no direct offset is added to the telescope elevation and azimuth axes; at every pointing step the selected increment is converted into an equatorial increment and previously added to the equatorial position to be converted into the to be alt-azimuthal telescope position.

5. – Pointing precision due to the software interface

The value of the *pointing errors* defined at the end of sect. **3** for both telescope elevation and azimuth axes is constantly displayed and is affected by the velocities and accelerations required for the telescope to track the target.

The value of the *time delay* described at point a) of sect. **3** is recovered—at any pointing step—by the software interface from an external source (a data file): thus errors are greater when tracking conditions would require a rapid and strong update of such delay time value, especially if quite different for the two different telescope axes (elevation and azimuth). As a consequence

a) in such tracking conditions a *constant value* of the time delay is a good approximation—*i.e.* far from midday and far from the summer solstice period—such errors may be less than 0.2 arcseconds; this optimum value can be considered as the precision of the architecture of the software interface.

b) In such conditions a *rapid and strong update* of the value of the time delay would be needed—*i.e.* around midday in the summer solstice period—such errors may reach a value of 1 arcsecond or more.

At present a simple dynamic feedback control of the value of such time delay is allowed: the mean values of the errors and the velocities for both azimuth and elevation are computed over 300 consecutive pointing steps (*i.e.* 30 seconds) and then the following correction is made to the last value used for the time delay:

$$\frac{1}{2}\left[\frac{\langle \mathrm{err(azimuth)}\rangle}{\langle \mathrm{vel(azimuth)}\rangle}+\frac{\langle \mathrm{err(elevation)}\rangle}{\langle \mathrm{vel(elevation)}\rangle}\right].$$

6. – Short-term pointing precision and user guided scans

The procedure used to perform a single step in a scan on the solar disk is illustrated in fig. 3: a) the observer uses the Instrumental Control Unit (UCCI) to require the TGSI

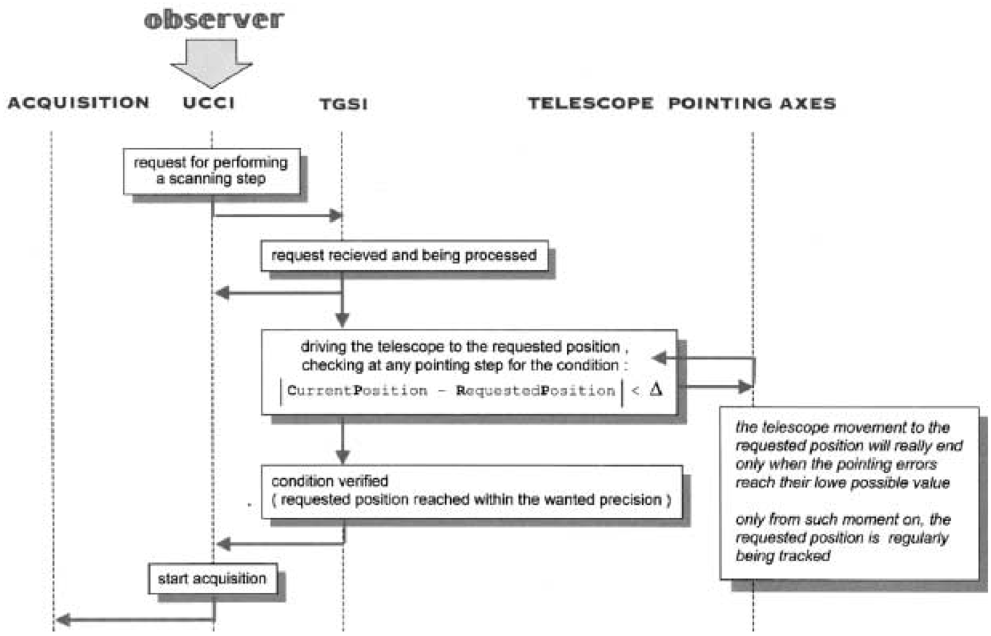

Fig. 3. – Scheme of the procedure used to perform a step during a scan on the solar disk.

to drive the telescope to a desired position and b) when the position is said to be reached the acquisition is started.

Three variables are involved in such a process:

1) telescope *pointing errors* values at the moment the scan is performed;

2) the *scanning step* value assigned by the observer;

3) the Δ parameter value assigned by the observer (see fig. 3).

We see that the lower limit to the scanning step value is the current telescope pointing errors value.

We also see that an optimum value is to be chosen by the observer for the Δ parameter with respect to the pointing errors:

a) if lower, the position is never said to be reached and thus the acquisition is never started, resulting in a comunication error;

b) if much higher, even if the position is said to be reached and thus the acquisition is started, the telescope will still be moving to complete the scanning step with a precision defined by the current pointing errors—which may imply image motion during acquisition.

REFERENCES

[1] Standish *et al.*, *JPL Lunar and Planetary Ephemerides* (Willmann-Bell Inc., Richmond VA) 1997.