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Automatic Determination of the SLR Reference Point at Côte d'Azur Multi-Technique Geodetic Observatory

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Abstract

The Satellite Laser Ranging (SLR) station known as GRSM-7845 in the International Laser Ranging Service (ILRS) is hosted by the Observatoire de la Côte d'Azur (OCA) located in Caussols, France. Its reference point is the intersection of the telescope axes, which is supposed to be static. Measuring devices and a data processing chain were set up to automatically determine this point, more quickly and accurately than traditional local survey. In order to use an indirect approach (circular fitting), circular and motorized prisms were fixed on the station to be always visible during the telescope rotation. A software package was developed to control the telescope, the dome and the total station motions for fully automatic measurements. In addition to providing an easy determination of the cross-axis for local ties, this system will allow to study the potential motion of the telescope's axes intersection throughout the year.

Keywords

Automation · Instrumentation · Local tie · Metrology · SLR

1 Introduction

The *Observatoire de la Côte d'Azur* (OCA) hosts permanent geodetic stations in Grasse area ("Grasse co-location site", Caussols, France). The relative positions of the reference

points of these instruments, hereafter named local tie vectors, are essential for the International Terrestrial Reference Frame (ITRF) construction and should be known at one millimeter accuracy (Altamimi et al. 2017; Poyard et al. 2017). More specifically, the satellite laser ranging (SLR) station GRSM-7845 which belongs to the International Laser Ranging Service (ILRS) network performs daily distance measurements. It is one of the few telescopes in the world capable of laser ranging on the Moon (Lunar Laser Ranging) (Chabé et al. 2020). Its reference point is the intersection of the telescope axes.

Currently, local tie vectors are determined once a year during a multi-technique local survey (Pesce 2013; Poyard 2009). However, this is a time-consuming operation during which the telescope cannot perform satellite measurements. Moreover, it requires specific metrology accessories and trained surveyors. Thus, this paper describes measuring devices and data-processing chain set up to automatically determine the reference point of the SLR station.

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2 Measuring Devices

2.1 Methodology

The SLR reference point is determined by an indirect approach (Dawson et al. 2007). For this, reflector targets are fixed on the SLR telescope. During the telescope rotation, these reflectors draw circle arcs. They are shot at different telescope angles by a motorized total station, located on the roof of the building, about forty meters away from the SLR station (Fig. 1). Moreover, several circular prisms are set up all around the SLR station, on concrete pillars and buildings. The normal vector to the circle plane that passes through the center of the circle defines the axis of rotation. By performing these measurements for both elevation and azimuth axes, the SLR reference point can be determined as the axes' intersection (Fig. 2). Physically, the axes do not necessarily intersect: this sub-millimeter distance is called "axis offset". The reference point is therefore defined as the orthogonal projection of the horizontal axis (elevation axis) onto the vertical axis (azimuth axis).

Measuring devices were developed to achieve automatic measurements, namely pendular prisms and a motorized corner cube. The four steps of field measurements are the following:

1. Retrieve meteorological data (to apply corrections later in post-processing).
2. Shoot all reference prisms shown in Fig. 1.
3. Shoot the pendular prism in several telescope elevation positions. For this, the telescope is positioned in front of the total station, see Sect. 2.2.
4. Shoot the motorized corner cube in several telescope azimuthal positions. The telescope is positioned at 90 degrees of elevation during these sessions, see Sect. 2.3.

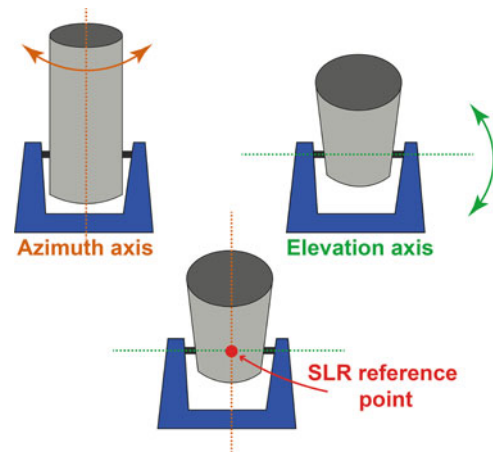


Fig. 2 SLR reference point defined as the intersection of elevation and azimuth axes

Measurements with the total station are performed on face left and face right, with intermediate closures to ensure validity of measurements.

2.2 Elevation Axis Measuring Devices

Several prisms are placed on telescope to determine elevation circles (Fig. 3). They have counterweights to always face the total station. At the beginning of the measurements, the telescope is positioned at an elevation of 5 degrees facing the total station. The total station shoots the pendular prisms in the two circles every 5 degrees of telescope elevation, up to the limit of 90 degrees (example of three steps in Fig. 4).

For a faster center determination, just one pendular prism can be targeted (i.e. one circle of elevation). In this case, the elevation axis is defined as the normal vector to the circle plane that passes through the center of this single circle. To

Fig. 1 Overview of the Grasse co-location site configuration during a local tie survey

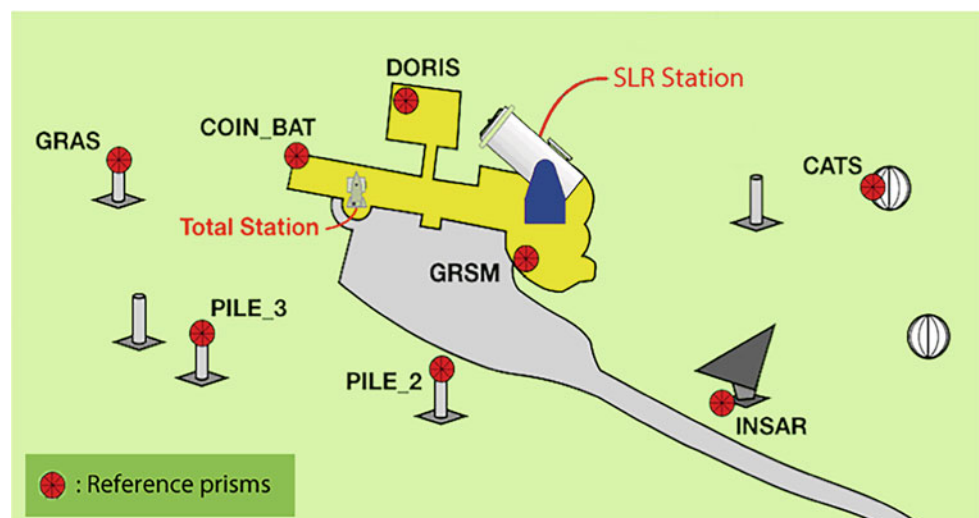


Fig. 3 Setup of a pendular prism on the telescope (left) and global view during rotation along the elevation axis (right)

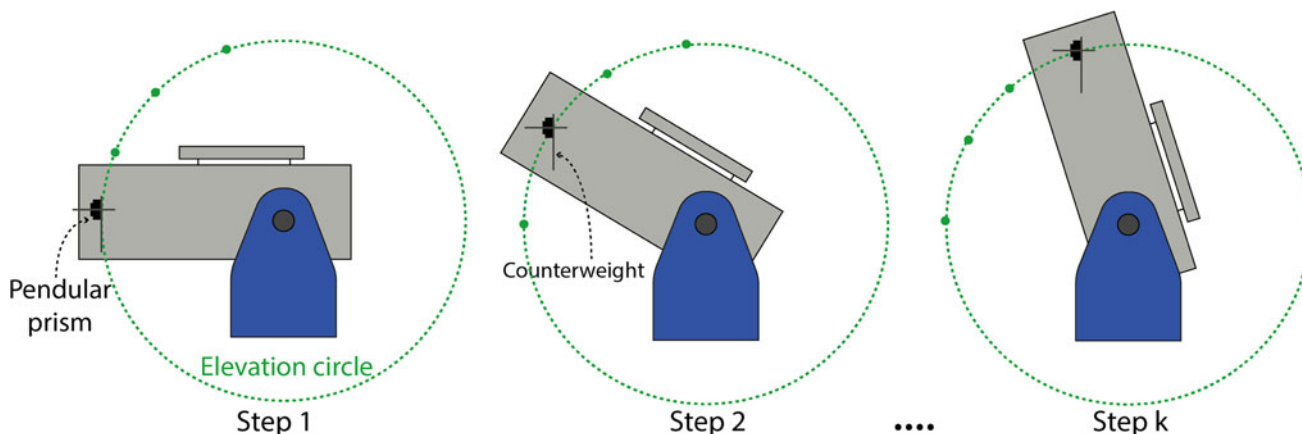
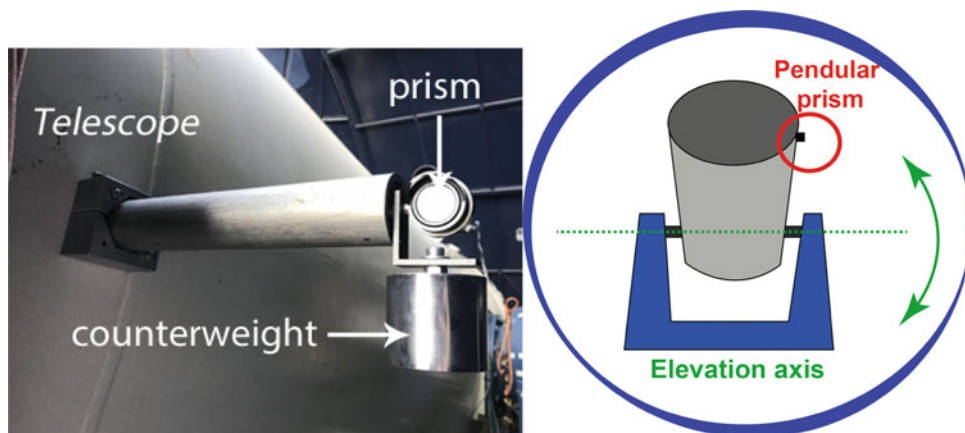


Fig. 4 Steps of elevation circle measurements. Thanks to counterweights, the pendular prism always faces the total station

improve the accuracy, up to three pendular prisms can be used (i.e. three circles determined). In this other case, the elevation axis passes through the center point of each circle.

the azimuth circle since the telescope masks the prisms when it is located behind (hidden area in Fig. 6).

2.3 Azimuth Axis Measuring Devices

When the telescope moves around its azimuth axis, a motorized corner cube is used as target. Indeed, this prism must rotate with telescope to be always visible from the total station: it is mounted on a stepper motor and driven by an Arduino microcontroller (Fig. 5). This device is fixed on a steel disc, located on the telescope fork. Figure 6 shows the device in four azimuthal positions of the telescope. Motor steps are automatically computed according to the number of points chosen by the user: it is adaptable, depending on the time available for measurement session or the required precision. A minimum of ten points is used to describe the circle.

Initially the prism is facing the telescope center thanks to an initialization sensor. This is the reference angle from which the motor steps will be calculated by trigonometry, to be directed toward the total station. As for the measurements of the elevation axis, points cannot be equally distributed on

3 Automation and First Measurement Tests

Now that we understand the principles of measuring axes and circles, it is important to coordinate the movements of the telescope, of its dome (to avoid masking prisms), of the total station and of the stepper motor. The *MeOCenter* software was developed to monitor all of them (Fig. 7).

From measurements to processing, it provides a complete determination of the SLR reference coordinates. In the software interface, the user can choose to determine a single axis or to have a complete determination of the center (azimuth and elevation axes). The total station and the stepper motor are respectively driven by a Raspberry Pi and Arduino microcontrollers. Arduino communication is provided by serial port via the Firmata protocol whereas the MeOCenter software communicates with the telescope, the dome and the total station via Sockets through the OCA computer network.

Fig. 5 Arduino circuit and setup (left) and global view during rotation along the elevation axis (right)

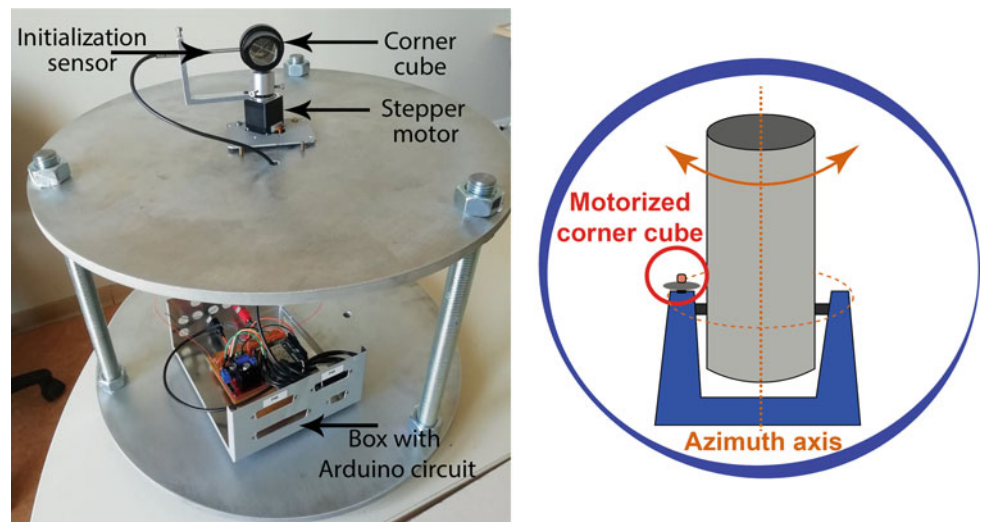
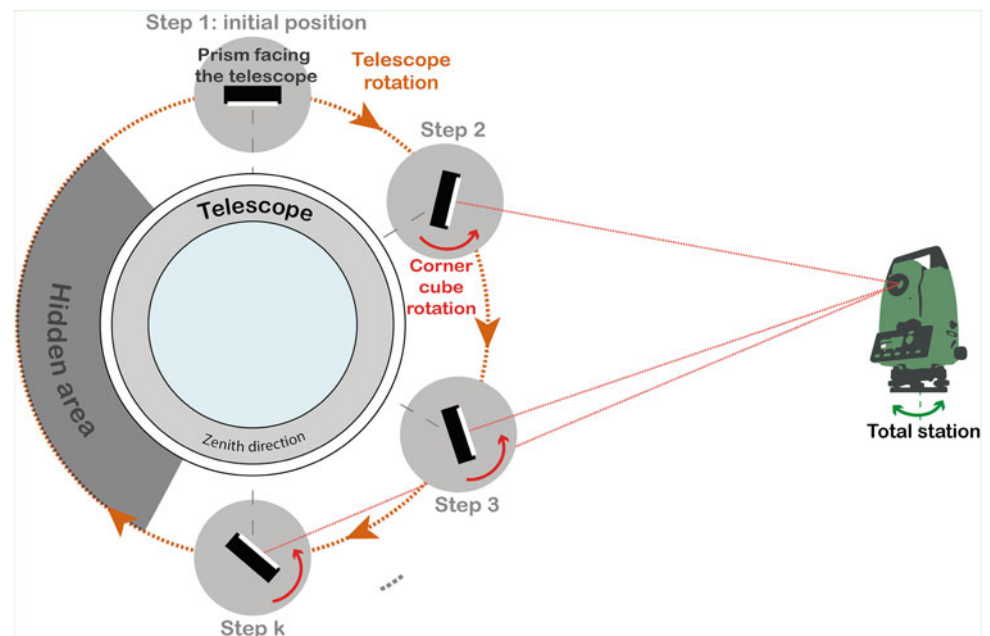


Fig. 6 Steps of azimuth circle measurements. With stepper motor, the corner cube is always visible from the total station after telescope rotation. The telescope is pointed upwards, in the zenith direction (top view, four steps shown)



At the end of the measurement process, the angle and distance data provided by the total station are formatted in a text file. They are sent to a Linux server where the Comp3d5 software is installed, in order to calculate the point coordinates in a local projected coordinate system. Comp3D, developed by IGN-France, is a micro-geodesy compensation software that implements a global 3D least-squares adjustment of several topometric observation types (Pesce 2013). The coordinates computed are sent back to the *MeOCenter* client by Sockets. Then the parameters of elevation and azimuth circle axes are determined by least squares circular regressions of these points. Finally, the SLR reference point is estimated by the orthogonal projection of the elevation axis onto the azimuth.

Since the implementation of the automatic method on GRSM-7845 station, several test sessions have been per-

formed. As shown in Fig. 8, the four determinations agree at the sub-millimeter level. Now, measurements should be continued to monitor the reference point position with the change of seasons or after a maintenance operation of the telescope.

4 Conclusion

This study aimed to automatically determine the SLR reference point at the Grasse co-location site. The project combines mechanics, electronics and IT developments. Thanks to the developed devices and software package, a continuous monitoring of the telescope reference point is made possible. Nevertheless, a total station has to remain permanently on

Fig. 7 The different components of the MeOCenter software package: communication with telescope, cupola, total station and measuring devices (by sockets, serial)

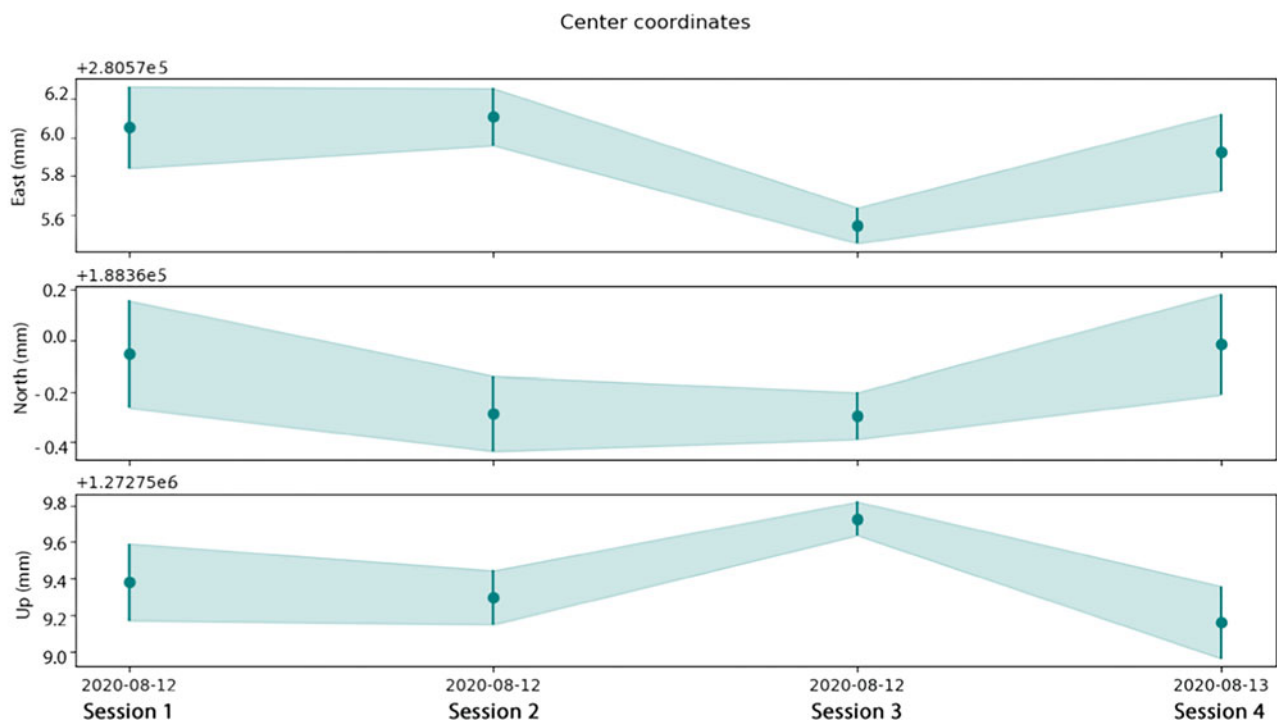
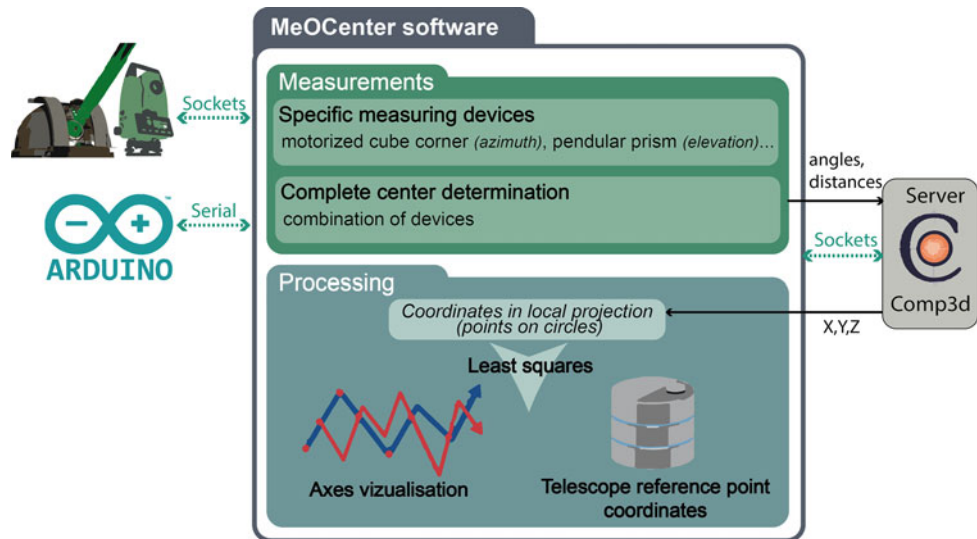


Fig. 8 Computed SLR reference point coordinates provided in a local coordinate system during different measurement sessions

the site to continue the measurements, which is not yet the case. However, this setup has been used during the last yearly local tie survey carried out in April 2021. More regular measurements are necessary to verify the SLR reference point position throughout the year, especially at seasonal time scale. As a perspective, several reflectors may be added

to the GNSS and DORIS antennas of the Grasse site (see Figure 22 in Poyard et al. (2017)). Thus, it could be possible to perform an entire automated re-measurement of the local tie network. More generally, this system on the SLR station could be adapted to a VLBI telescope and set up at another co-location site.

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