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Towards an autonomous telescope system: the Test-Bed Telescope project

E. Racero[1,2], F. Ocaña[1,2] and D. Ponz[1], on behalf of the TBT Consortium

[1] Facultad de Ciencias Físicas, Universidad Complutense de Madrid, 28040 Madrid, Spain
[2] ISDEFE, European Space Astronomy Centre, 28692 Villanueva de la Cañada, Spain

Abstract

In the context of the Space Situational Awareness (SSA) programme of ESA, it is foreseen to deploy several large robotic telescopes in remote locations to provide surveillance and tracking services for man-made as well as natural near-Earth objects (NEOs). The present project, termed Telescope Test Bed (TBT) is being developed under ESA's General Studies and Technology Programme, and shall implement a test-bed for the validation of an autonomous optical observing system in a realistic scenario, consisting of two telescopes located in Spain and Australia, to collect representative test data for precursor NEO services.

It is foreseen that this test-bed environment will be used to validate future prototype software systems as well as to evaluate remote monitoring and control techniques. The test-bed system will be capable to deliver astrometric and photometric data of the observed objects in near real-time. This contribution describes the current status of the project.

1 Introduction

The purpose of the SSA programme is to provide an independent capability to acquire prompt and precise information regarding objects orbiting the Earth. Using this data, a wide range of services will be provided, such as warning of potential collisions between these objects or alerting when and where debris re-enters the Earth's atmosphere. These data will be stored in a catalogue, made available to SSA customers across Europe. The infrastructure required to provide these capabilities comprises surveillance and tracking sensors to acquire the raw data, which are then processed to correlate the detections with known objects, or to identify a new object if this has not been seen before.

Ground-based optical sensors are very efficient systems to detect and track faint objects in high altitude orbital regions, due to their inherent sensitivity advantage over radars for this task. However, these sensors are subject to the variations of atmospheric weather, which can result in the inability to track or observe objects as frequently as desired, which in turn may lead to difficulty re-acquiring the objects at a later date. In order to deal with the atmospheric variability and to implement efficient surveillance and tracking strategies, it is foreseen that the final SSA system will consist of several large robotic telescopes in remote locations to provide efficient surveillance and tracking services for space objects within the Earth immediate surroundings.

It is important to indicate that during the last years, a number of robotic telescope network systems have been deployed for astronomical purposes [1]. In fact, this is a new observing technology that complements the installation of large observing facilities. Robotic telescope networks are essential tools for observing gamma-ray bursts, monitoring of blazars, supernova searches, study of active galaxy nuclei, exoplanet searches and asteroid surveys. The technology is now mature enough to be adapted to the requirements of the ESA SSA programme.

2 Location

The architecture of the ESAs Optical Surveillance System Test-Bed involves two optical observing systems in two different geographical locations controlled remotely from a Control Centre located at ESA premises, ESOC (European Space Operation Centre) as a first option. To minimize logistic problems during the deployment and operation of the Test-Bed, two ESA deep space stations (DSS) are proposed as initial locations for deployment of the system: at Cebreros DSS, in Spain, and at New Norcia DSS, in Western Australia.

Although the simultaneous observation of the same area of the sky will not be possible with this configuration, weather permitting, it will allow the coverage of most of the Northern and Southern Sky at the same time, the follow-up of any Earth orbiting object in any orbital position and continuous NEOs visibility. Weather conditions in both places are quite optimal for optical observations. However, although good enough for the test-bed purposes, the conditions for astronomical conditions are not the best. Light pollution is low in the two locations but it is foreseen that the low altitude of the considered places will imply moderate seeing.

Complementary, these infrastructures guarantee the availability of power supply, IT network and security services. The first option considered for the Control Centre of the Test-Bed is a centralized control system located at ESOC in Darmstad, Germany. Both test bed observing systems will be operated from there and these will be linked through it with the ESA SSA programme infrastructure and the observation, data processing and archiving infrastructures of other SSA and NEO programmes.

3 Hardware Configuration

The goals of the project define the main characteristics of the telescope. The system will execute short exposures (in the range of seconds) across the whole sky, leading to a need of a fast mount. In order to cover enough fields along the night the size of the field of view (FoV) comes as a result of a trade-off between the resolution and the size of the optics. Based on the Statement of Work requirements for the optical configuration, there are two main drivers considered for the hardware design:

- Object detection with magnitude $V = 18$ with SNR$= 3$ within a 2 seconds exposure.
- Minimum FoV of $2.3^\circ \times 2.3^\circ$ should be ensured.

The final optical configuration selected is a custom fast prime focus astrograph with f/2.52, an aperture of 560 mm and a FoV of $2.5^\circ \times 2.5^\circ$, allowing an acceptable plate scale of $2.52''\mathrm{pix}^{-1}$.

Regarding the telescope mount, a direct-drive equatorial mount was selected for the project. In a direct drive configuration, the right ascension and declinations axes are actually the motor shafts, and electromagnetic clutches are used to hold the mount in a certain spot with minimal friction and close to zero backlash. The performance of this system is above other drive methods, with tracking precision that could reach $< 1''$ in 120 min, pointing accuracy of the order of $5''$ RMS and moving speed up to $20^\circ\mathrm{s}^{-1}$.

The camera market survey was led by the preliminary results on the optical design. In order to ensure the whole FoV coverage at the primary focal plane, the linear size of the CCD should be around 61 mm. The only standard sensor with that size is a CCD with 4096×4096 pixels, with a pixel size of 15 μm. The final camera model purchased for this project is a Spectral Instruments 800 Series with a e2V back-illuminated CCD.

4 The Software Solution

The main challenge of the project is the development and implementation of the software solution for the automatization of the observatories, from the pure real-time control module to the processing and scheduling of the global net. The project has to use as many COTS software components as possible to reduce costs and to improve the system performance making use of the state-of-the-art in robotics telescopes. Nevertheless, additional developments are being carried out for each of the components of the final software architecture in order to meet the specific requirements of the project.

The overall software system, depicted in Fig. 1, is based on four main modules: control, scheduling and processing. Each module is based on existing software modules to be tailored to the project requirements and it is in charge of a well-defined and specific set of functions providing a flexible and robust software solution as a whole. In addition, it is customary the development of the different interfaces between the software components in a coordinated way due to the level of dependency among them so the system presents a high-level of automatization.

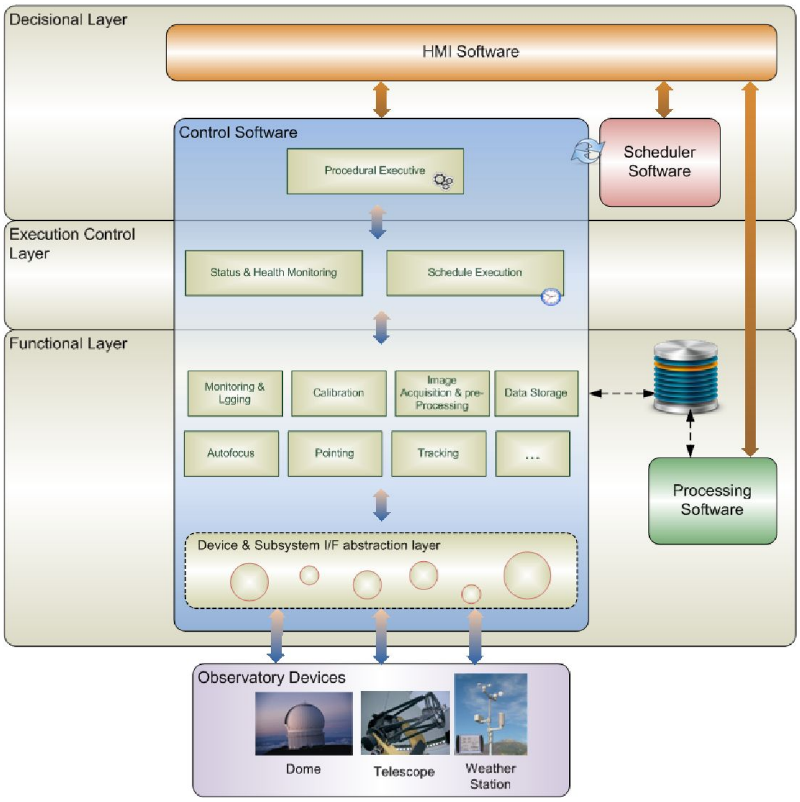

Figure 1: Software high-level architecture.

4.1 Control Software

The development of the Remote Telescope System (RTS2; `http://www.rts2.org/`) started in 2002. It is an open source package with the aim to create a modular environment for observatory control, that could cope easily with a change of camera, mount, or weather sensor, that would enable script-driven operation, and permit automatic (and fast) reaction to emerging targets of opportunity, most notably the Gamma Ray Burst (GRB) localizations.

RTS2 central server is the core of the software. It communicates through RTS2 protocol with the telescope, device drivers (like cameras, dome, weather station, etc.), executor and selector that through predefined strategies select next object to be observed. All communication is done through TCP/IP, only from camera to camera driver USB is used. Control and data transfer between components does not delay the observation in any way. The architecture of RTS2 is shown in Fig. 2.

4.2 Planning and Scheduling

The scheduling tool will implement two general observing strategies for space objects, that is Survey and Follow-Up. The Survey strategy aims at the detection of new objects for different

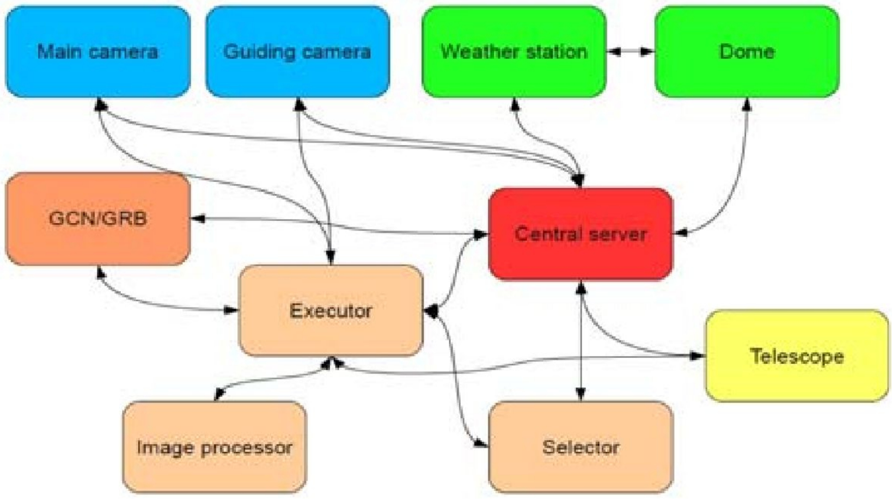

Figure 2: RTS2 architecture.

target population speeds, whereas the Follow-Up goal is the detection of objects in need of revisit.

The software component in charge of both manual and automatic planning and scheduling of the system is the TBT scheduler, based on a previous manual scheduling tool developed by Isdefe for the CESAR[1] project. The main tasks of the software are:

- Implementation of survey and follow-up strategies.
- Automatic generation of the Short Term Plan (STP) for each telescope, defined as the observing plan of a particular night within hours of the starting night.
- Rescheduling Operations and Target of Opportunity operations.
- Management of the global observing strategy of the SSA-TBT system.

The TBT scheduler is conceived as a high-level planning tool for the manual and automatic planning that will be executed by the telescope control software or RTS2. The scheduler will generate the Short Term Plan for the night, thus it will be responsible for the definition and management of the global strategy for the SSA-TBT observatories, and relies on the RTS2 internal meta-queue system for the real-time response and monitoring of the system. Once the night starts, the scheduling tool will be in charge of the rescheduling

[1]Cooperation through Education in Science and Astronomy Research

operations, monitoring changes in the MPC[2] web service and through its own interface, providing a near real-time response during the night.

4.3 Processing

The final processing software package chosen for this project is TOTAS, developed by Matthias Busch and currently used to process NEOs survey images taken at the OGS observatory. It is based on the commercial astrometric data reduction package PinPoint which scans a set of 3 images of the same sky area. From this starting point, the TBT consortium is currently working on its development to include the processing of streak-images in order to increase the sensitivity when targeting high speed objects that otherwise will not be possible to resolve. Finally, TOTAS also incorporates a web service that allows direct confirmation of possible space objects candidates by users.

5 Final Remarks

The Test-Bed project started in November 2012 funded by the ESA GSTP programme, with reference G532-004GR, titled: Demonstration Test-Bed for the Remote Control of an Automated Follow-Up Telescope. Next milestone is the test readiness review, scheduled in May 2015.

At this moment the hardware components are undergoing final assembly and will be delivered by January 2015 at the first site, after Factory Acceptance Test is successfully passed. The software development to meet the statement of work requirements is also currently ongoing, to be delivered by the first semester of 2015 pending on the final tuning after hardware deployment on-site.

Acknowledgments

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In memoriam Daniel Ponz. For us you will be always in the stars.

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