Boletim da Sociedade Astronômica Brasileira, **292**, no. 1, 292-294

A robotic observatory

ROCG — Remote Observatory of Campos dos Goytacazes

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Abstract. This work aims to present the automation focused on the astronomical observatory built in the Campos dos Goytacazes region and share the acquired experience in the process to collaborate with the astronomical community.

Resumo. Este trabalho objetiva apresentar a automação voltada ao observatório astronômico construído na região de Campos dos Goytacazes e disponibilizar para outros interessados a experiencia adquirida no processo para colaboração com a comunidade astronômica.

Keywords. Telescopes – Instrumentation: miscellaneous – Astrometry

1. Introduction

The ROCG Observatory — REMOTE OBSERVATORY OF CAMPOS DOS GOYTACAZES began construction in February 2016 and completed its installation on October 12 of the same year. In 2020, the observatory facilities were expanded, and it is currently undergoing the development of new activities. Its first light was on October 12, 2016, and it is located in the city of Campos dos Goytacazes, in the state of Rio de Janeiro, owned by Carlos Henrique Barreto, an electrical engineer and physics undergraduate (author), available for monitoring lunar impacts, observing asteroids, comets, Near-Earth Objects (NEOs), and other observations within the scope of its technical capabilities, such as planetary observations, deep-sky objects, and other activities related to amateur and cooperative astronomy with science.

Designed according to technical standards in the field of amateur observation, the observatory featured a motorized dome and a Celestron C-14 Schmidt-Cassegrain telescope. For the automation of the observatory, the Velleman K8055N control interface was used for dome control and switches, following the LesveDomeNet project. The observatory dome is the system responsible for equipment protection, reducing exposure to winds and mitigating light pollution. In the center of the dome is the astronomical telescope, and depending on the angle and region of the sky to be observed, the dome must rotate and position the shutter, which is a window to the sky. The dome rotation is performed using a sliding surface driven by a 12V 40rpm DC motor with a torque of approximately 50 Nm. The positioning is synchronized with the telescope pointing, based on accurate information about the object to be observed and the reading of the shutter position obtained through a rotary encoder.

In order to open the shutter and make the chosen sky region visible, a 12V 30rpm 35Nm DC motor system was implemented, along with the installation of magnetic limit sensors. The rotation and opening process is fully computer-controlled, allowing for the control of the observatory without the need for human interaction, thus providing greater efficiency in observations. For this purpose, a Velleman K8055N IO interface was implemented, enabling input and output of information and creating an interface between the computer, telescope, and dome.

2. Automation and security

2.1. Cloud Sensor

The process of opening the dome without human presence could leave the observatory vulnerable to extreme weather conditions such as rain and wind. In other words, the observatory could open or remain open during these conditions, potentially causing damage to the equipment. To address this risk, a rain protection system was developed, which involves detecting rain clouds.

For the detection system, an Arduino UNO board and ambient temperature and infrared sensors were used. Through the Arduino IDE, an algorithm was developed to read the background sky temperature and compare it with the ambient temperature.

According to Souza, Echer, and Martins (n.d.), the Earth's surface absorbs the incident solar radiation and re-emits it in the infrared spectral range (0.77-1000 μm, Long Wave - LW). Clouds act as agents that trap the infrared radiation emitted by the surface and the atmosphere, similar to the greenhouse effect.

Based on this knowledge, it is understood that the temperature return reflected by the sky increases in the presence of clouds. By interpreting the sensor readings, specific values were determined to indicate dense clouds with a high probability of rain. These values were then incorporated into the algorithm for decision-making purposes.

3. Theoretical Framework

Integrated software applications using the ASCOM driver (Medkeff, 2000) allow for complete robotic control and remote operation of the observatory in a safe and autonomous manner. The scheduling and pipeline for data processing and reduction are made possible by the proprietary software suite: TAO, SkySift, and SearchScheduler (Holvorcem, 2015). The overall control and operations integrated with the ASCOM driver enable observational missions to be carried out remotely or in situ.

To protect the internal equipment from rain and high humidity levels, a cloud detector was constructed as a security system that allows operations and observation only when there are no dense clouds. Digital infrared and analog sensors are connected to Arduino for this purpose. In the event of a power outage, the observatory is designed to safely shut down, as it is connected to an uninterruptible power supply (UPS). The IO interface includes an input to identify the power supply system, whether it is the UPS or external grid, to ensure immediate closure and prevent the observatory from remaining open due to a power failure.

For more precise sidereal tracking, it is necessary to refine the alignment between the polar axis of the equatorial mount and the Earth's rotation axis (geographic north-south line). This alignment process can be time-consuming, lasting for hours or even nights until the correct adjustment is achieved. In addition to precise alignment, the telescope mount needs to have a positioning system that can detect and correct periodic errors. Encoders are recommended for telescope mounts to achieve this. One way to save time on alignment is to have the telescope permanently aligned with the celestial south pole at a fixed station. This requires a structure, known as an astronomical observatory, to protect the equipment from natural elements such as the sun, rain, dust, and wind. The observatory will house the telescope and its instruments.

The first step in constructing an observatory is to determine the type of study to be conducted, the size and weight of the instrument, the connected equipment, and the available computer resources. Choosing CCD cameras for image acquisition is important, and they should be equipped with cooling systems to reduce thermal noise in long exposures. An external all-sky camera is used to observe the sky conditions when the observatory is closed, and internal cameras are used to monitor the interior images during or after autonomous operations (robotics), allowing for remote inspection of the observatory's functioning.

The selection of internet connection speed is also important to ensure sufficient upload rate for remote access, as a large amount of data is sent in real-time from the observatory to the researcher. The construction of an astronomical observatory requires careful planning, including the selection of a suitable location often in areas far from urban centers with minimal light pollution that competes with celestial body brightness. With the use of band-pass filters, it is still possible to construct observatories in locations with moderate light pollution, as these filters reject artificial light wavelengths and allow the passage of celestial light. These resources are available at ROCG.

It is also important to seek locations with suitable atmospheric conditions (turbulence and visibility) for astronomical observations. Thanks to computer graphics and astronomical image processing software, we can mitigate the effects of turbulence in images. At ROCG, Registrax is used for planetary images (Auriga Imaging).

4. Results and Conclusions

The ROCG consists of a 2.2-meter diameter fiberglass dome, a Newtonian reflector astrophotography telescope with an f/4.8 focal ratio and a 254mm diameter, equipped with a 3" AG Wynne coma corrector from Órion. It is mounted on an iOptron Cem60EC equatorial mount with a precision of 0.06 arc seconds. The observatory utilizes a FLI16803 CCD camera from the microline series, with a maximum resolution of 4096x4096 pixels / 16.8 Mpx and a diagonal of 52.1mm.

The construction of the observatory was carried out by the author, using open-source control and automation software. An Arduino-based mini weather station was implemented, utilizing open-source software, to monitor clouds and provide rain alerts.

The overall control and remote operations of ROCG utilize software integrated with the ASCOM driver, allowing all observational missions to be carried out remotely or in situ, in an autonomous and secure manner, with minimal human intervention. The operations are scheduled and include data processing and reduction pipelines, facilitated by the proprietary software systems TAO, SkySift, and SearchScheduler.

Figure 1. ROCG Observatory external image

From the perspective and principle of citizen science, ROCG maintains a regular observation program for NEOS (Near-Earth Objects) and transient phenomena detection.

Acknowledgements. We would like to thank Centro Universitário Internacional UNINTER for the technical and scientific support provided.

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Figure 2. ROCG Observatory internal image

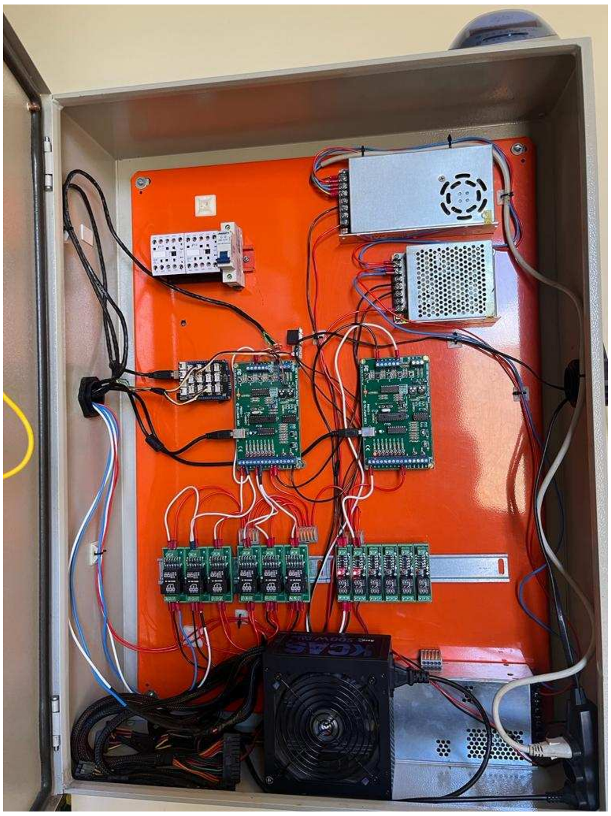

Figure 3. Automation interface

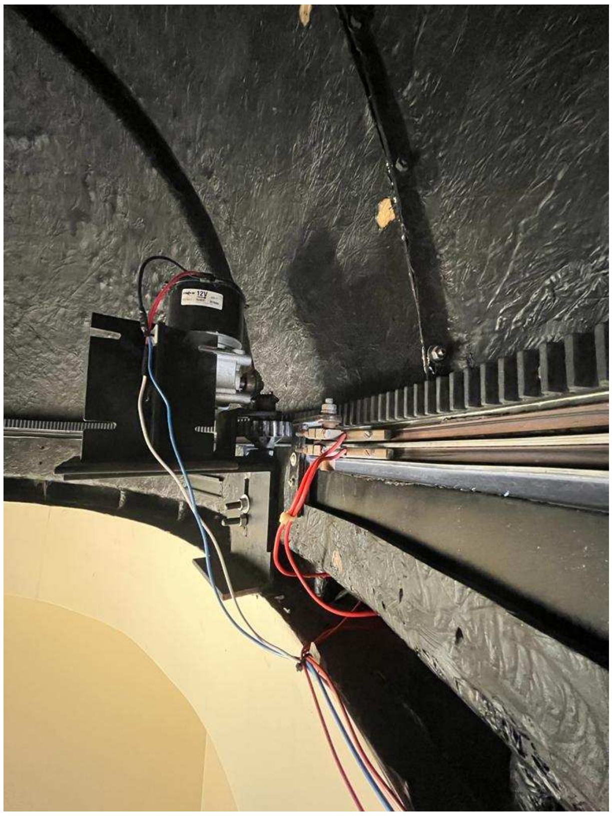

Figure 4. Trapdoor rotation motor

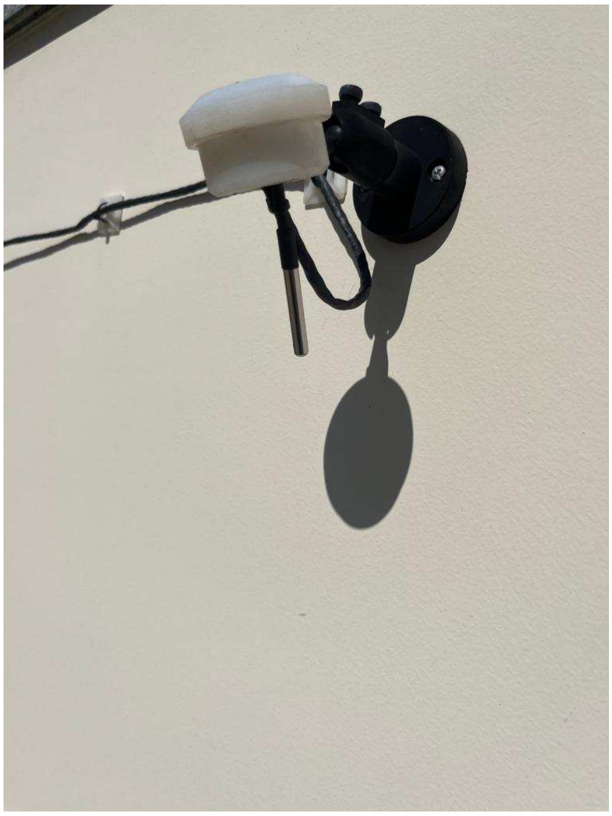

Figure 5. Cloud Sensor