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The Carl Sagan solar and stellar observatories as remote observatories

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Abstract. In this work we summarize recent efforts made by the University of Sonora, with the goal of expanding the capability for remote operation of the Carl Sagan Solar and Stellar Observatories, as well as the first steps that have been taken in order to achieve autonomous robotic operation in the near future. The solar observatory was established in 2007 on the university campus by our late colleague A. Sánchez-Ibarra. It consists of four solar telescopes mounted on a single equatorial mount. On the other hand, the stellar observatory, which saw the first light on 16 February 2010, is located 21 km away from Hermosillo, Sonora at the site of the School of Agriculture of the University of Sonora. Both observatories can now be remotely controlled, and to some extent are able to operate autonomously. In this paper we discuss how this has been accomplished in terms of the use of software as well as the instruments under control. We also briefly discuss the main scientific and educational objectives, the future plans to improve the control software and to construct an autonomous observatory on a mountain site, as well as the opportunities for collaborations.

Keywords : autonomous – telescopes – pipeline

1. Introduction

Since late nineties, the Astronomy Area of the University of Sonora has been interested in building a remote as well as autonomous observatory at an excellent mountain site called Cerro Azul (Saucedo et al. 2001) located in northwestern Mexico, 200 km away from Hermosillo, Sonora. However, the logistic aspects have proven to be very challenging for a median size university like ours for several reasons, one of which being of course, funding. These problems have caused that at the time of writing, the

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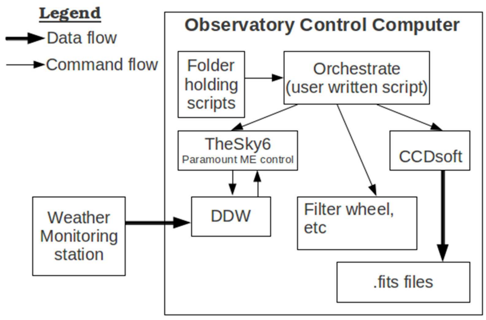

Figure 1. Data and command flow

mountain observatory has not been constructed. Meanwhile, we decided to build a fully operational prototype observatory at a relatively dark site not too far from Hermosillo, on the land of our university, part of the School of Agriculture. This is how the Carl Sagan Stellar Observatory (CSSO) came-up, an observatory that could be used as a technology and methodology test-bed, equipped with a telescope and science instruments. Building on the university property immediately provided several advantages like lower construction cost, water, electricity, Internet, easy reach, and last but not least, security. Around year and half after the first light, the CSSO prototype could function in a remotely controlled mode, could also work autonomously. It is expected to be fully operational this year, dedicating most of its time to search for supernovae and several other projects.

The Carl Sagan Solar Observatory could be operated remotely but so far, not autonomously. A general overview of the equipment and operational details is offered in the present work.

2. Operation of the Carl Sagan Stellar Observatory

The observatory uses ASCOM-compliant software, which allows considerable flexibility in hardware implementation while making it user-friendly for astronomers. The general arrangement of software can be seen in Fig.1, where the two main forms of operation are shown i.e. as a stand alone automated observatory and a remotely controlled one. As it is shown, the main origin for data flow is the user interface in the case of remote control or the use of scripts in the case of automated operation. In both cases (TheSky6, 2004) plays a crucial role. Specifications on both forms of operations are discussed next.

2.1 Remote operation

While in remote mode, the observatory works pretty much as if it were being locally operated but replacing the console in the observatory for the user's remote computer monitor where all relevant software can be accessed by the user. In this mode, control of the Paramount ME mount and rotating PD15 dome is done via TheSky6 software, while image control is done through CCDSoft. The control of the dome is mostly automatic, except the opening and closing operations. Movement of the dome is done by the TheSky6 software via a vendor-supplied plugin.

2.2 Autonomous operation

This form of operation allows the observatory control computer (OCC) a complete control over observatory operation and data-gathering functions. In this mode, the user writes scripts that are to be loaded in the OCC and will be executed with no human intervention, a great advantage during the whole observing session. The software architecture used in this case is presented in Fig. 1. The Orchestrate script is the source of commands for the OCC and all science-related hardware. The data transfer from the weather station has the sole purpose of warning and taking action in adverse conditions. The general layout of an automated observing night agenda is as follows:

1. Orchestrate software, running in the OCC, will continuously scan a designated listening folder for scripts to be executed. The naming of the script file in this folder (computer directory) will determine the order in which the commands are to be executed. It is important to note that Orchestrate will load a script from a folder containing several files, considering ONLY the naming order and not the time or date. Hence, once the first script by naming order is completed, the second one will be loaded regardless of the time.
2. Once a script is loaded, the OCC will start to execute its commands in order. Here the user (writer of the script) can choose the time for work to begin using Orchestrate's 'WaitUntill' command at the first line, where the argument can be at a certain hour and date. Note that this will halt all operation of the OCC until the time and date are reached. One can, for example, have the particular script loaded (by naming order) from the folder (at whatever time this happens) and have the computer waiting, until a certain date and time to start operation. The usefulness of this command is apparent if you want to send instructions in, for example, a weekly basis with special tasks to be undertaken each day. It should be noted that special care needs to be placed in writing the scripts, and in particular, the end of operation instructions. Details about this as well as any other aspect of observatory operation via scripted control must be inspected by the observatory administrator prior to execution.
3. Once the observing session ends and the equipment is properly stored and deactivated, the user will transfer all data files to his (her) own computer for processing and analysis.

The user should consider that a weather station feeds data to the OCC in order to permit automatic closure of the dome and proper storage of the equipment in case of adverse weather imperils the safety of the observatory, or simply, because adequate observing conditions are lost. This will interrupt the execution of the script with no direct notice to the user (unless he/she is directly monitoring the observatory). Operation in autonomous mode may be considered "simple", provided an appropriate script is written, and this can be achieved by using TheSky6 scripting menu, this will permit quick writing of a script including multiple objects arranged according either to RA, Dec or by letting it choose the best route to be followed by the telescope. Options like exposure time, temperature setting of the CCD camera and filter selection are similarly easily introduced.

Figure 2. The stellar observatory: AstroSib 500 telescope mounted on a Paramount ME.

Figure 3. The solar observatory: suit of telescopes mounted on a Celestron CGEpro.

3. Equipment of the Carl Sagan Stellar Observatory

As of May 2011, the observatory operates with the following installed observational equipment (other cameras are also available):

- Telescope
  Model: AstroSIB 500
  Aperture: 0.5 m
  Focal ratio: f/8
  Optical Design: Ritchie-Chretien
- Mount
  Model Paramount ME
- CCD Camera

Model: Apogee Alta U 9000
Chip Size: 3056×3056 pixels (12×12 microns each)
Imaging area: 36.7×36.7-mm
Mounted on the AstroSib 500 the Apogee Alta U 9000 gives a field of view of 31.6×31.6 and pixel resolution of 0.62 seconds of arc/pixel.

- Filter Wheel
  AI-FW50 Filter Wheel - 7 Position for 50-mm Square Filters
- Dome
  PRO-DOME (PD15)

4. The Carl Sagan Solar Observatory

The Carl Sagan Solar Observatory is located in the university main campus. It is currently being used to record solar activity, as well as for education and science outreach, and has been in operation with the current telescopes since 2007, but has been recently updated in science instruments (new telescope mount, and high resolution cameras) as well as software to improve both movement (pointing and tracking) and image acquisition of higher quality. Remote control of this observatory is possible and available for research/education purposes to researchers/teachers by solicitation to the authors. The equipment at present is:

- Telescopes
  - 16-cm f/7.5 custom made (David Lunt) refractor with H-alfa (656.3 nm, bandwidth 0.05 nm)
  - 16-cm f/7.5 custom made (David Lunt) refractor with Ca II (393.3 nm, bandwidth 0.1nm)
  - 70-mm f/5.7 Coronado SolarMax 70 H-alfa telescope
- CCD Cameras
  2 Lumenera SKYNyx 2-2 one in each of the 16-cm telescopes, using a 1616×1232 pixel chip (4.4 μm pixels).
  1 Lumenera SKYNyx 2-0 in the MaxScope, using a 640×480 pixel chip (7.4 μm square pixels)
- Mount
  Celestron CGEpro
- Dome
  Astrohaven: clamshell 12 ft

5. Final discussion

Both the Carl Sagan Solar Observatory and the Carl Sagan Stellar Observatory are in operation. The first one is normally controlled remotely from a building contiguous to the solar observatory dome, but it can also be controlled from anywhere, with appropriate devices connected to the Internet. Orchestrate is currently used to execute several automatic operations, unfortunately not all, that are required for fully autonomous operation. For example, we have not been able yet to operate the Lumenera cameras with Orchestrate. For the the stellar observatory, all operations could be controlled with the Orchestrate. Furthermore, it has been more thoroughly tested than the solar observatory, therefore we have certain confidence that it will perform well if we decide to operate it autonomously. However, thanks to information we gathered at this Workshop on Robotic Autonomous Observatories, it is now clear to us that it would be highly recommended that we change the telescope control system to a linux-based RTS2 (Kubanek 2006) control software. Thus, we are planning to make this transition in the near future. We also believe that building a prototype of the stellar telescope was a good decision, because its short distance from town has allowed us to solve problems faster than we would if it were on the mountain. In fact, we think that this experience brings us closer to our objective of having a mountain observatory. Furthermore, the closeness of the observatory permits visits of students interested in learning observational astronomy.

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