Telescope Control through CelestialGrid

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ABSTRACT

The Remote Observatory for Variable Object Research (ROVOR) is a 16 inch RC Optical telescope sited 12 miles NW of Delta Utah. Observatory communication and control on ROVOR is provided through a Java software package called CelestialGrid. CelestialGrid was entirely built at Brigham Young University and is an all-inclusive observatory system which automates the capture, retrieval, calibration, reduction, and long-term archival of astronomical data. CelestialGrid is a software framework built on top of Software Bisque Orchestrate, The Sky, and CCDSoft for telescope operation. Although CelestialGrid was developed for use on ROVOR, the system is modular and is capable of controlling many different observatories.

Keywords: Astronomy software, CelestialGrid, observatory automation, robotic telescope, remote systems, telescope control.

1. INTRODUCTION

CelestialGrid is a software package designed from the ground up to minimize human interaction with the observatory and telescope systems. Reduced interaction leads to fewer human introduced errors and enables researchers to focus on the science of astronomy and not the mechanics of nightly observation. Although CelestialGrid requires further development, its current release represents a significant step forward in automating observatories at Brigham Young University.

1.1 Background

Why automate an observatory? The most obvious reason may be that an astronomer does not always want to stay up all night operating a telescope. Such operation is often tedious, time consuming, and error prone. Thus, an automated observatory with specific programmable routines simplifies observational astronomy.

Another reason for automating an observatory is to enable researchers to coordinate research efforts for variable targets of opportunity. Variable targets of opportunity are astronomical objects which periodically "flare" or "burst" in brightness. These changes in brightness are often hard to predict and last for brief time intervals. In particular Gamma-ray bursts (GRBs) are extremely energetic objects that flare in the high energy gamma spectrum. Although the GRBs are not observable from the surface of Earth, orbital space detectors transmit GRB coordinates to the surface for an optical spectrum followup. A GRB can last for as short as a few minutes or as long as multiple days. Because the time domain is uncertain, it is critical that ground based observatories quickly and accurately followup with GRB sightings; a robotic observatory is ideal for the task.

A blazar is an active galactic core. Blazars are similar to GRBs in that they periodically flare over widely varying time domains. Although it happens often, the cause of this flaring is unknown. Catching them while they are flaring is essential to understand the physics behind the blazars. Undergraduate students Cameron Pace and Richard Pearson successfully monitored the blazar Markarian 501 throughout 2008 and 2009 (see Figure 1). Using data from ROVOR, both Cameron[1] and Richard[2] published their senior theses in 2010. Because of robotic observatories, we are able to accurately monitor and quickly follow up on flaring blazars.

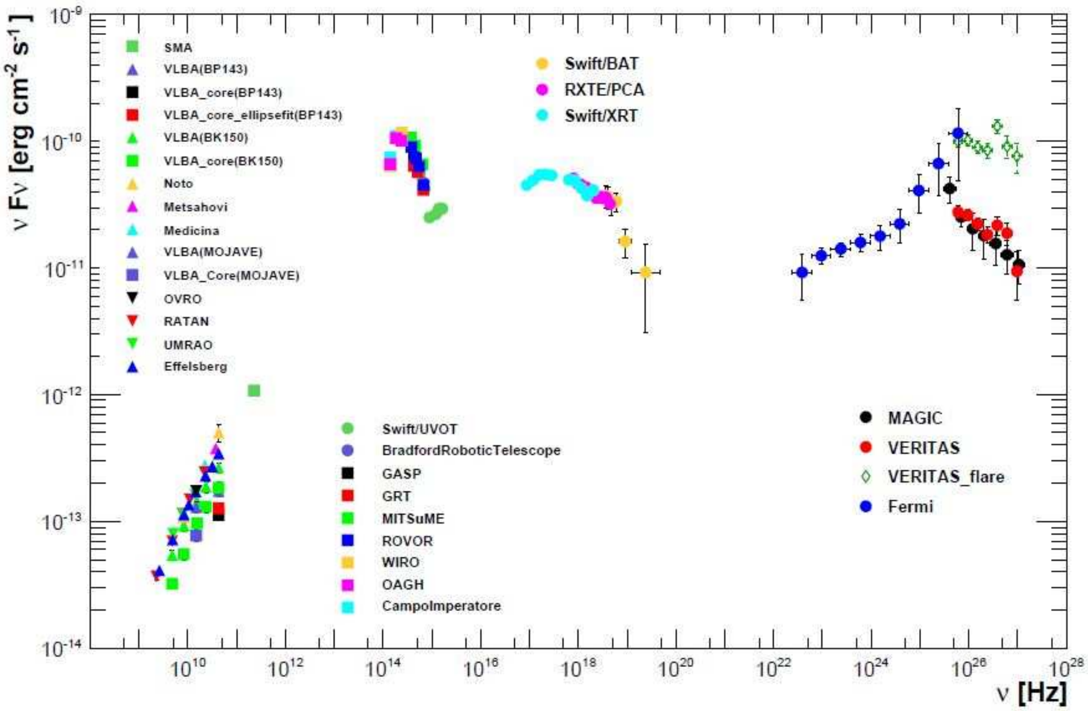

Figure 1. Data from the active galaxy Markarian 501. ROVOR data is compared to data from observatories around the world.[3]

1.2 The Remote Observatory for Variable Object Research

The Remote Observatory for Variable Object Research (ROVOR)[4] is a 16 inch RC Optical telescope sited 12 miles North West of Delta Utah. It has been built to remotely monitor bright objects that vary with time such as variable stars, cataclysmic variables, GRBs, and active galactic nuclei (AGN) including blazars, quasars, Seyfert nuclei and Low Ionization Nuclear Emission Regions (LINERS). ROVOR has been designed from the ground up with off the shelf materials, making it a cost effective tool for modern astronomical research.

CelestialGrid was originally designed to simplify the operation of ROVOR. Communication with ROVOR was originally done entirely through remote desktop. A user would remote desktop into the system, manually open the dome, turn on power to the telescope and equipment, and load an Orchestrate script to start observing. This system of operation continued for the first year of ROVORs operation. Initially, problems primarily arose due to the limited internet connection. Often the observatory was inaccessible simply due to the slow internet connection. The slow internet connection also made remote operation troublesome and error prone.

Despite being problematic, throughout its first year of operation ROVOR successfully provided research quality data. Specifically, ROVOR successfully observed the active galaxy Markarian 501 throughout the year 2009. Figure 1 shows data from ROVOR of Markarian 501 being compared to data from other observatories from around the world. In addition to AGN research, previous undergraduate student Richard Pearson successfully recorded a GRB afterglow on April 30, 2010 (see Figure 2).

Due to the troublesome nature of operating ROVOR, development of CelestialGrid began during the Winter of 2010. The first successful operation of ROVOR took place during June, 2010. Since assuming full control of observatory operations in Fall, 2010, ROVOR, through CelestialGrid, has continued to provide data of AGNs and GRBs.

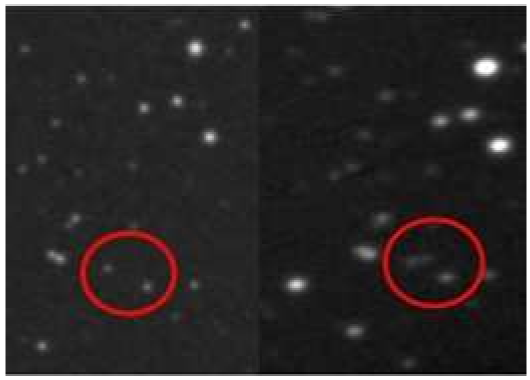

Figure 2. Recorded in the Gamma-ray burst coordination network as GCN Circular #9318, undergraduate student Richard Pearson used ROVOR to capture a Gamma-ray burst optical afterglow.

2. CELESTIAL GRID SYSTEM SUMMARY

In this section, I present a summary of the software architecture of CelestialGrid. CelestialGrid itself has two separate components: a client side application (CelestialGrid Client), and the main server software (CelestialGrid Server). The client needs to be installed on the observatory computers and the server software is run at the university or on a personal computer. Throughout the technical discussion of CelestialGrid, refer to Figure 3 for a schematic on how the system is set up on ROVOR.

2.1 Software Description

The software of CelestialGrid is almost exclusively developed in *Oracle Java* with access to a *MySQL* database. This development choice enables the software to be platform independent on the server side of the application. The client side of the application requires *Microsoft Windows*. The software is distributed and packaged as a *Java Web Start* application. *Java Web Start* technology enables all installations of the server software to automatically update on startup. The graphical user interface heavily relies upon the Java graphics libraries *Abstract Window Toolkit* (AWT) and *Swing*. The CelestialGrid source code is thoroughly documented through *Javadoc*.

CelestialGrid is built around the server control system, with clients installed at observatory locations. Communication between the server and client instances is managed through the CelestialGrid Protocol. This network protocol defines how the system communicates through a Transmission Control Protocol/Internet Protocol (TCP/IP) connection. The main purpose of the CelestialGrid client is to process remote commands from the CelestialGrid server by interfacing with local software installed on the observatory computers.

CelestialGrid Server also provides a batch utility (command-line) for archiving images from all connected observatories. Images may be automatically or manually retrieved from remote observatories. Because automatic retrieval is slow depending on the internet connection speed, data can also be retrieved manually and entered into long term storage. The image files themselves are archived on high capacity storage hard-drives. In order to minimize data loss due to hardware failure, these hard drives should be placed in a RAID configuration. Automatic retrieval is performed through the File Transfer Protocol (FTP). Files to be transferred include: web camera images, image data files, weather data files, and *Orchestrate* scripts. After images are taken and downloaded back to the university, they are archived into a *MySQL* database. Header information on each image is stored in this database.

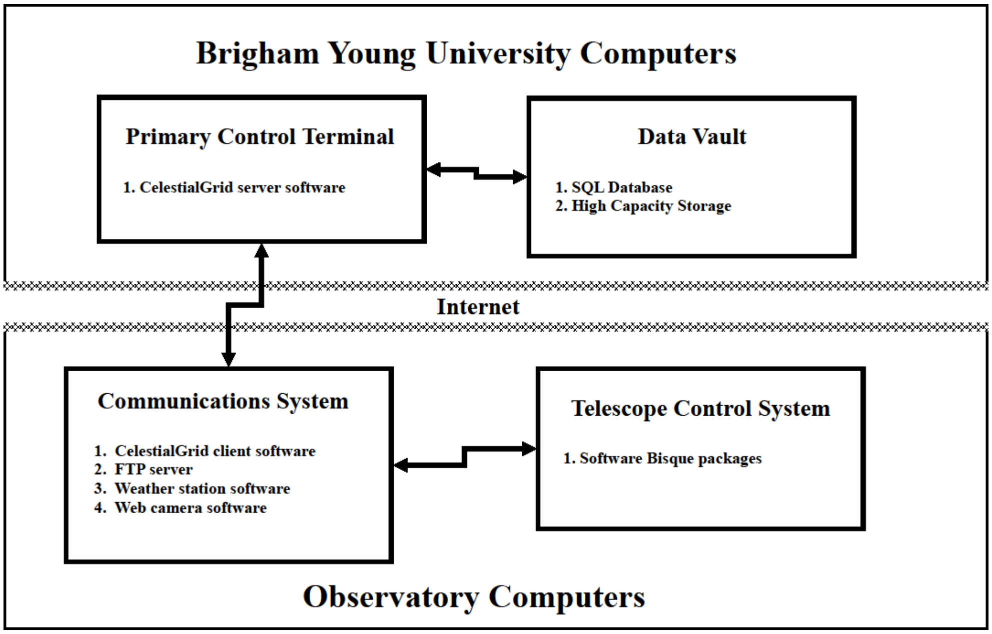

Figure 3. A schematic of how CelestialGrid is set up on ROVOR. Although the schematic says that CelestialGrid Server is run at BYU, the software can be installed and launched from any location.

3. FUTURE DEVELOPMENT

Now that CelestialGrid has been exclusively operating ROVOR since August 2010, our attention has turned towards future development. There are multiple features that are planned to be implemented within CelestialGrid. These features will improve the overall system security and functionality.

1. World Coordinates System - World Coordinates coefficients need to be implemented within every image that comes out of CelestialGrid. These coefficients provide an immediate translation between x/y pixel positions and right ascension and declination coordinates. Having these coefficients in the FIT header of each image is required for availability in the National Virtual Observatory.
2. User login interface - Develop a user login interface that accepts multiple connections to the observatory. Each user will have a designated password. All images and command logging from CelestialGrid would be tied to the user that issued each command. This will improve security and functionality, as some users could have read only access.
3. Automatic Scheduling Interface - Develop an interface which takes care of all object scheduling. CelestialGrid would simply be supplied a set of objects to image throughout the year. The objects could have different priority levels. The scheduling interface would then automatically build observation tasks from night to night. It would know which, when, and for how long objects in the given set are viewable. On its own, the system would schedule observing from night to night. This is a crucial step in making ROVOR not only robotic and automatic, but completely autonomous.
4. Automatic Photometry - Our current setup is limited by the speed and bandwidth of our internet connection. Every night we download hundreds of images. This can take all day to finish. Instead of downloading images back to BYU, we would like CelestialGrid client to automatically calculate the photometry of every star on every frame each night. In the morning, pure magnitude values could be downloaded back to BYU much more quickly. These values could then be archived in the *MySQL* database. Automatic graphs and charts of nightly results could also be emailed to users.

4. CONCLUSION

Due to the development of CelestialGrid, the Remote Observatory for Variable Object Research is now fully robotic and is moving toward complete autonomy. The system has enabled researchers at Brigham Young University to focus on the science of astronomy and not the mechanics of nightly observation. CelestialGrid was developed to be implemented on many different observatories. Therefore, if researchers are interested in using CelestialGrid or obtaining the source code, contact information is available at http://rovor.byu.edu.

REFERENCES

[1] C. Pace, Senior thesis, Brigham Young University, 2010.

[2] R. L. Pearson, Senior thesis, Brigham Young University, 2010.

[3] Abdo et al., ApJ 2011.

[4] J. W. Moody, B. Little, M. Abbott, J. Barnes, B. Boizelle, K. Bates, J. Nelson, C. Pace, R. Pearson III, and A. Sadun, "The Remote Observatory for Variable Object Research (ROVOR)," Telescopes From Afar, (2011).