Astronomical Dome Control System Based on ASCOM and Modbus/TCP Protocol (Postprint)

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Abstract

The dome is an important peripheral device for astronomical telescope systems. With the development of telescope technology, dome control technology has continuously advanced. To achieve full automation of the automated differential image motion atmospheric seeing monitor at Yunnan Astronomical Observatory, a dome control system based on ASCOM and Modbus/TCP protocols was developed. By combining the ASCOM astronomical technology standard and Modbus/TCP protocol specification, the system architecture and implementation methods are introduced in detail. Practical test results demonstrate that the system exhibits good stability and compatibility, fully meeting the requirements of automated observation, and provides experience and methodology for dome design of small and medium-sized astronomical telescopes.

Full Text

Astronomical Dome Control System Based on ASCOM and Modbus/TCP Protocol

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Abstract

The astronomical dome is a critical peripheral component of telescope systems. With advances in telescope technology, dome control technology has continuously evolved. To achieve full automation of the Automatic Differential Image Motion Monitor (ADIMM) at Yunnan Observatory, we developed a dome control system based on the ASCOM standard and Modbus/TCP protocol. Drawing upon the ASCOM astronomical technical standard and Modbus/TCP protocol specifications, this paper details the system architecture, operational principles, and implementation methodology. Experimental results demonstrate that the system exhibits excellent stability and compatibility, fully meeting the requirements for automated observations and providing valuable experience and methodology for the design of small-to-medium-sized astronomical telescope domes.

Keywords: Astronomical Dome; ADIMM; ASCOM; Modbus/TCP

1. Introduction

The astronomical dome serves as a vital protective enclosure for telescope systems, shielding instruments from adverse weather conditions such as wind and rain. As ground-based optical telescope technology has advanced rapidly, dome technology has garnered increasing attention. Traditional domes feature an openable skylight and typically rotate to assist telescope tracking. Modern dome designs increasingly incorporate factors such as improved dome seeing, reduced wind resistance, and minimized vibration. With scientific and technological progress, astronomical dome products have become more diverse, intelligent control technologies and communication protocols have been seamlessly integrated, and domes have entered an era of intelligent automation.

The ADIMM (Automatic Differential Image Motion Monitor) at Yunnan Observatory employs a clamshell folding dome structure, which offers cost-effectiveness and convenient control. Since the manufacturer did not provide a control system, we independently developed a Modbus/TCP-based dome control system and enhanced it with ASCOM (Astronomy Common Object Model) support for improved compatibility and extensibility.

ASCOM, proposed by Bob Denny in 1998 for the DC-3 Dreams Astronomy Control Panel (ACP), is an open astronomical interface standard that introduces a driver layer between control software and hardware devices. It provides a free, interoperable platform for astronomy software vendors and instrument manufacturers. Compared to embedded control code or closed, non-extensible drivers, ASCOM' s advantages are evident: equipment manufacturers need only provide ASCOM-compliant drivers to integrate their devices into the ASCOM platform, while control software can operate uniformly without concerning itself with device-specific peculiarities.

Modbus/TCP is an open industrial fieldbus protocol based on Ethernet, first introduced by Modicon in 1999. In 2008, China officially released the national standard GB/T 19582-2008 "Modbus Industrial Automation Network Specification,"which has promoted widespread adoption in industrial control applications. The Ethernet link layer checksum mechanism ensures data packet integrity, eliminating the need for additional data verification. By strictly adhering to the Application Data Unit (ADU) specifications, reliable data transmission can be achieved over Ethernet networks.

[Figure 1: see original paper] ASCOM schematic

Modbus/TCP Application Data Unit Frame Format

2. System Architecture

Based on the dual-opening characteristics of the clamshell folding dome, we selected a Schneider Zelio Logic programmable logic controller (PLC) with model SR3B261BD and Ethernet communication module SR3NET01BD as the dome controller. The left and right dome sections are controlled independently through separate drivers and motors. Limit switches for opening and closing serve dual functions of motion limiting and status feedback.

The system operates in two modes: (1) automatic computer control via Modbus/TCP protocol, and (2) manual control through a physical control panel. The weather station is an essential peripheral for automated dome operation. While computer-connected weather stations are common, we prioritized real-time reliability by directly connecting rain/snow sensor signals to trigger the dome controller.

System design emphasizes operational safety and stability. For maintenance personnel safety, control buttons utilize non-latching normally-open configurations, with emergency stop buttons deployed inside the dome to immediately halt motion and minimize injury risks. To protect the telescope from severe weather, the automatic mode incorporates dual-layer protection: the first layer from the weather station and the second from communication failure monitoring, which automatically closes the dome after 60 seconds of inactivity to prevent failures caused by control software or network communication issues. Additionally, left and right dome sections cannot operate simultaneously to prevent collision.

[Figure 2: see original paper] System schematic

3. Software Design

The software comprises two components: the PLC control program and the computer-side ASCOM driver. The PLC program is written in function block diagram language, referencing the dome control system from Yunnan Observatory' s BOOTES (Burst Observer and Optical Transient Exploring System) for compatibility.

The PLC I/O configuration includes: I1 for weather signals (close dome command), I3-I6 for emergency stop buttons, and I7-I10 for limit switches (left-open, left-close, right-open, right-close). The program performs logical judgments on these inputs and controls four relay outputs to operate the left and right dome motors, achieving the opening and closing functions.

[Figure 3: see original paper] PLC Program diagram

The computer-side ASCOM driver is developed in Microsoft Visual Studio 2010 using C#. The dome driver essentially consists of properties and methods compliant with the ASCOM Dome class standard. Key properties include CanSetShutter (whether shutter control is supported), ShutterStatus (shutter state), and Connected (connection status). Primary methods are OpenShutter() and CloseShutter().

Common Properties and Methods of Dome Class

The software flow involves three stages: device connection, dome operation, and disconnection. The driver initiates network connection using the configured IP address and port, setting Connected=True upon success. To open the dome, it first checks if ShutterStatus=Closed, then sends an open command to the dome controller via OpenShutter() and initiates a timer (<1s) to periodically query dome status until ShutterStatus=Opened. Closing follows a similar process but first disables the timer to prevent re-opening.

[Figure 4: see original paper] Software flowchart

A critical design consideration is treating the clamshell folding dome as a non-slewing classic astronomical dome, with opening/closing operations analogous to classic dome shutter operations. This approach significantly reduces software complexity while maintaining reliability. Since control software calls ASCOM drivers with specific time cycles, synchronous communication for time-consuming operations like status queries would cause blocking and software freezing. Our design implements reasonable network communication timeouts and employs non-blocking thread-based timers, completely resolving communication blocking issues.

[Figure 5: see original paper] Connection configuration

4. Implementation and Testing

Manual control for the ADIMM dome was implemented earlier and has operated without hardware or software failures. The system has been tested extensively with control software including MaxIm DL, MaxPilot, and TeamViewer remote login control. Screenshots demonstrate successful dome control operations.

[Figure 6: see original paper] Dome control interface
[Figure 7: see original paper] Dome control interface

The Windows-based ADIMM control software has successfully implemented Modbus/TCP protocol control of the dome. Future development will gradually add ASCOM support to enable compatibility with more third-party software. ASCOM support was added in 2016, and the system has demonstrated excellent performance.

5. Conclusion

ADIMM is a site-monitoring instrument independently developed by Yunnan Observatory. Given its fully automated, unattended operation characteristics, dome automation is crucial. The ASCOM and Modbus/TCP-based dome control system demonstrates excellent stability, compatibility, and scalability. Test results confirm it provides reliable assurance for fully automated ADIMM observations and offers valuable experience for small-to-medium telescope dome designs.

The design also considers cross-platform compatibility. The Linux-based second-generation Remote Telescope System (RTS2) is gradually becoming a standard for remote telescope control. This dome control system's design provides prerequisite conditions and reliable assurance for future Linux-based ADIMM control software development.

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Note: Figure translations are in progress. See original paper for figures.