Postprint of the Dome Automation Control System for the 1.2-meter Telescope at Yunnan Observatories

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Abstract

Automated control of the dome is of great significance for improving the quality of observational data and reducing the workload of observational staff. For the special dome structure of the 1.2m telescope at Yunnan Observatory—where two hemispheres translate open to both sides and rotation is driven by rubber-wheel friction—an automated dome control system was developed using an architecture of on-site control by embedded control boards and remote communication via wired Ethernet. The embedded control board adopts FL2440 running a Linux system, dome position detection employs a combination of 8 Hall probes and 3 magnets, achieving higher position resolution, and a relatively detailed control instruction set is listed. After a two-month trial operation, the results show that the system is safe, stable, and reliable, meeting the requirements of daily observations.

Full Text

The Dome Automation Control System of the 1.2m Telescope at Yunnan Observatories

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Abstract

Automated dome control is crucial for improving observational data quality and reducing observer workload. For the 1.2m telescope at Yunnan Observatories, which features a unique dome structure—two hemispheres that slide open horizontally with rotation driven by rubber wheel friction—we have developed an automated control system using an embedded control board with local control and remote communication via wired Ethernet. The embedded board employs an FL2440 platform running Linux. Dome position detection utilizes eight Hall sensors combined with three magnets, achieving a position resolution of 15°. A detailed control instruction set is presented. After two months of trial operation, the system has proven safe, stable, and reliable, meeting the requirements of routine observations.

Keywords: Automation; Dome Control; Embedded System; Remote Control; FL2440

1. Introduction

The dome is an indispensable peripheral device for ground-based optical telescopes, providing both the working environment for observations and protection for the instrument. During observations, the dome should minimize impact on the observation process, while when not in operation, it should effectively seal the telescope from external elements such as wind and dust. Various dome designs exist in the field. Unlike typical astronomical domes with shutter openings, the dome of the Yunnan Observatory 1.2m telescope consists of two hemispheres that open to opposite sides [Figure 1: see original paper].

The 1.2m telescope is primarily used for space object observations, requiring the dome to rotate promptly according to target positions to avoid obstruction. Space objects move rapidly, and observation targets are frequently changed. The original control method used push buttons on a console to rotate the dome clockwise or counterclockwise via relay-controlled AC motors, requiring observers to constantly monitor the dome status. Although monitoring cameras are installed to determine when rotation is needed, limitations in field of view and camera placement make it difficult to detect obstruction promptly, resulting in degraded data quality.

[Figure 2: see original paper] illustrates the dome obstruction relationship. The dome opening center is fixed at 0° azimuth. For a given telescope azimuth, full obstruction occurs when the elevation is below the solid curve, partial obstruction occurs when below the hollow curve, and the dome becomes visible in the monitor field when below the solid line. Since the monitor visibility and partial obstruction elevation thresholds are close, by the time an observer sees the dome in the monitor, obstruction may have already occurred for some time. During photometric measurements, this appears as continuous target dimming, making it impossible in post-analysis to distinguish actual target variation from dome obstruction. The dome opening has a relatively large angular width.

The two most common astronomical dome control methods are full-opening and tracking modes. Full-opening mode completely opens the dome, eliminating any obstruction to the telescope, requiring only an initial opening before observation without further control. Tracking mode, the simplest form of which synchronizes dome rotation with the telescope to keep the tube always at the shutter opening, is mainly used for tracking slow-moving targets like stars. Tracking systems generally consist of two main components: drive motors and position measurement for strategic judgment. Traditional implementations use Programmable Logic Controllers (PLC) with photoelectric encoders for angle measurement. For solar targets, photoelectric elements symmetrically mounted on a Y-shaped bracket can track the sun based on differential light intensity. Fieldbus techniques have also been applied to dome tracking, particularly suitable for telescopes not originally designed for dome synchronization.

Due to its unique structure, the dome of the Yunnan Observatory 1.2m telescope cannot fully open. Furthermore, because the telescope is used for fast-moving space objects requiring frequent target changes, and because dome rotation vibrations significantly impact imaging observations, continuous tracking is not feasible. Therefore, we developed an automated control system that minimizes dome rotation while meeting non-obstruction requirements.

2. System Architecture

The automated control system primarily handles dome opening, clockwise/counterclockwise rotation to specified angles, dome closing, and various rotation modes including continuous rotation and shortest-path rotation to target positions. The system architecture employs local embedded control board management with remote communication via wired Ethernet [Figure 3: see original paper].

The dome control relays operate on AC signals, while typical embedded control boards output TTL-level signals. Therefore, voltage conversion is required to transform TTL signals into relay control signals. Safety considerations include mutual exclusivity between open and close signals, mutual exclusivity between clockwise and counterclockwise rotation signals, and mandatory time intervals between signal transitions. In case of software errors, hardware-level safety protection is implemented.

3. Position Detection

Dome position detection is essential for automated control. While conventional practice places encoders on the rotation axis, the 1.2m telescope dome uses dual-motor rubber wheel friction drive. Rubber wheel wear causes transmission ratio variations and slippage, making encoder-based solutions unsuitable. In practice, the required dome position accuracy is not extremely high, but a single Hall sensor zero-point approach is insufficient.

We adopted a non-contact Hall sensor approach using eight Hall sensors combined with three magnets to achieve position detection [Figure 4: see original paper]. Due to structural limitations, Hall probes cannot be placed too close, and the dome has a certain opening angle. The eight Hall sensors are mounted on the base at 45° intervals, numbered #0 to #7 clockwise. The three magnets are mounted on the dome’ s friction rotation plate at 15° intervals, numbered sequentially. When the center magnet aligns with the dome opening center, the position is defined as 0°.

The position detection scheme works as follows: when a magnet passes a Hall sensor, it triggers a signal. By identifying which sensor and which magnet triggered, the dome position can be determined with 15° resolution. The Hall sensors are normally-open type NJK-5002A, which produce Hall induction signals converted to 12V level signals for the embedded control board.

4. Initialization Procedure

Since the three magnets are identical and produce indistinguishable Hall signals, magnet identification requires knowledge of the previous Hall event and rotation direction. This makes initialization a critical consideration. The initialization procedure [Figure 5: see original paper] works as follows: when initiated, the dome rotates clockwise continuously. Upon first detecting a Hall signal, the target Hall probe is set to the next one clockwise (normalized to [0,7]), and rotation continues until the target probe triggers. The current Hall probe ID is saved, and the magnet ID is initialized to 0.

5. Control Logic and Hardware

The embedded control board (FL2440) is the system' s core component, responsible for parsing Hall signals, outputting control logic, and interpreting remote commands. Running Linux, it supports multithreading and network communication. Key hardware resources include a 400 MHz S3C2440A CPU, 100M Ethernet interface (DM9000), and GPIO ports for input/output.

The control logic signals include enable, open dome, close dome, clockwise rotation, and counterclockwise rotation. To prevent false triggering, all signals except enable are only effective when enable is active. When switching the enable signal, all other control signals are automatically disabled first to prevent anomalies from multiple simultaneous active signals. The enable signal is active-high, while other signals are active-low. During board power-on self-test, all output signals briefly go low then high to avoid simultaneous activation.

6. Control Instruction Set

Based on automation requirements, the control instruction set is defined in . The system operates in three modes: manual mode (push-button control), program control mode (software control), and autonomous mode (software decides rotation needs based on telescope position). During observations, autonomous mode is typically used. In this mode, with position detection precision of 15° and requirement for magnet-probe alignment, the dome normally rotates once per 30° of telescope azimuth change. Calculations show that when elevation exceeds 60°, no obstruction occurs, so dome rotation is unnecessary. For safety, the threshold is set to 45° elevation.

The instruction set includes commands for enabling/disabling automation, stopping rotation, initialization, continuous rotation, rotation to specified angles, and autonomous tracking. In autonomous mode, the system continuously receives telescope azimuth (Az) and elevation (El) to independently determine rotation needs, target angles, and direction.

7. Optimization and Software Implementation

The shortest-path rotation algorithm must consider the dome' s two-hemisphere structure. For example, with current dome position at 15° and target at 165°, clockwise rotation requires 150° while counterclockwise requires 210°, making clockwise the optimal choice. [Figure 7: see original paper] compares dome and telescope positions during a transit, showing that optimization significantly reduces rotation frequency and total rotation angle. Without optimization, 11 rotations totaling 510° are needed; with optimization, this reduces to 5 rotations totaling 225°.

The software consists of onboard server software running on the embedded board and client software running on a control computer, communicating via TCP/IP. The server software, developed in C under Linux, monitors Hall signals and calculates position, parses instructions, and outputs control signals. The client software, developed in C++ under Windows XP, obtains telescope azimuth and zenith distance via serial port, implements autonomous control logic, and sends commands to the server. The graphical interface [Figure 8: see original paper] allows mode selection and status monitoring.

8. Results and Discussion

After two months of trial operation, all control instructions execute correctly, and the autonomous mode functions properly, meeting routine observation requirements. However, one issue emerged: due to inertia and installation tolerances, when the dome stops, the magnet may be positioned exactly over the Hall probe or may overshoot it. Since Hall detection only triggers on falling edges, reverse rotation cannot be correctly detected if the magnet remains over the probe.

A simple solution was implemented: after detecting a Hall signal, the dome continues rotating an additional small angle before stopping, ensuring the magnet leaves the probe' s range. This guarantees correct detection during reverse rotation. In autonomous mode, the dome rotates once per 30° of telescope azimuth change, keeping the telescope pointing near the dome opening center. Given the dome' s large opening angle, further optimization using predictive algorithms could reduce rotation frequency.

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Abstract: Dome automation is very important for improving data quality and reducing observers' workload. For the dome of the 1.2m Telescope at Yunnan Observatories, an automation control system is designed to avoid the occlusion effect caused by the dome during observation. The dome has a special structure with two hemispheres that can be opened horizontally with its rotation driven by tire friction. This auto control system uses an embedded system to control the dome by voltage conversion and remote network communication. The embedded device is FL2440 and its operating system is Linux. This architecture uses 8 Hall sensors and 3 magnets to determine the position of the dome. Test indicates that its position resolution accuracy reaches to 15°. Details of the instruction set are given. After two months of trial, we find that the system is secure, stable and reliable. It can also meet the needs of regular observations.

Keywords: Automation; Dome Control; Embedded System; Remote Control; FL2440

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