23MAT112- Mathematics for intelligent Systems 2

24AIM111- Introduction to data structures and algorithms

TELESCOPE CONTROL SYSTEM

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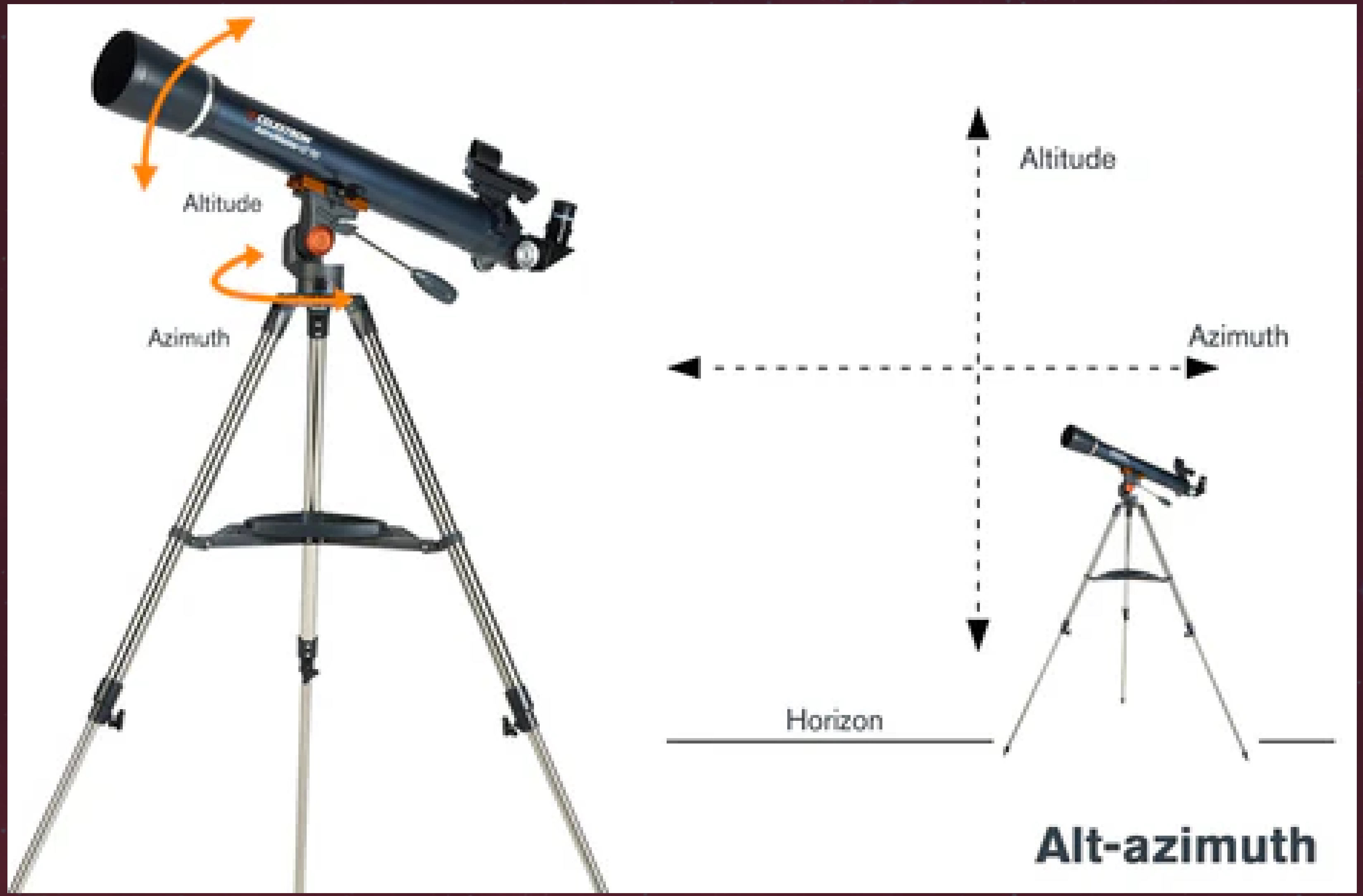
PROBLEM STATEMENT



Telescopes require precise and stable movement to track celestial objects accurately. However, factors like mechanical imperfections, external disturbances, and computational delays can lead to tracking errors and inefficient control. There is a need for an optimal control strategy that ensures smooth telescope motion while efficiently managing control commands.

PROPOSED SOLUTION

Designing a real-time telescope control system using the LQR algorithm for precise and smooth movement. The system will use a Euler's method to solve the differential equations while minimizing tracking errors and energy usage.

TELESCOPE MODEL

Differential Equations used to model the telescope

1. **θ (Altitude angle)**

$d\theta/dt=\omega_\theta$

$d\omega\theta/dt=(-b_\theta*\omega_\theta)/I_\theta$

2. **φ (Azimuth angle):**

$d\phi/dt=\omega_\phi$

$d\omega_\phi/dt=(-b_\phi*\omega_\phi)/I_\phi$

Where:

$I\theta, I\phi$: Moments of inertia

$b\theta, b\phi$,: Damping coefficient

LITERATURE REVIEW

Sl. no.	Title	Year	Methodology	Key Contributions
1.	A Systematic Methodology for Modeling and Attitude Control of Multibody Space Telescopes	2024	Kane's method for multibody modeling, Linear Quadratic Regulator (LQR) design.	Developed a systematic method for modelling multibody space telescope.
2.	Execution of Queue-Scheduled Observations with the Gemini 8m Telescopes	1997	Queue scheduling, dynamic simulation models.	Proposed an efficient queue-based scheduling model for telescope operations.

3	**Pointing Accuracy Improvements for the South Pole Telescope with Machine Learning**	**2024**	Two XGBoost models were trained using historical telescope observation data, and weather conditions to predict real-time corrections.	Achieved a 33% reduction in pointing errors, enabling more precise observations.
4	Model Predictive Star Tracking Control for Ground-Based Telescopes: The Telescopio Nazionale Galileo Case	2024	A two-layer MPC-based tracking system is designed, to track astronomical targets while mitigating disturbances.	Achieved superior tracking accuracy, robustness to wind disturbances, and improved performance over traditional PID and LQG-PI controllers, validated on the Telescopio Nazionale Galileo (TNG).

LINEAR QUADRATIC REGULATOR (LQR)

LQR is an optimal control technique
LQR is used to minimize the deviation of the system’s state such as angular position from a target state.
LQR-based controllers improve the angular accuracy and minimizes energy consumption.

Control Effort:
It refers to how much energy is required to adjust the telescope to the target position.

LQR

- Stabilizes the telescope
- Minimizes control effort
- Reduces oscillations

STATE SPACE FORM:

$$\dot{x} = Ax + Bu$$

Where:

A-How the sytem moves without the influence of the control input

X-State Vector

U- Control input

B-How the control input affects system's state

DSA IMPLEMENTATION: LINEAR QUEUE

Queue: A queue is a linear data structure that follows the FIFO (First-In-First-Out) principle, meaning the first element inserted is the first one removed.

Operations on a Queue:

- append(x): Adds an element x to the back of the queue.
- pop(): Removes an element from the front of the queue.

Why Queue over array?

- Automatically maintains the order of elements(FIFO).
- Automatically discards old elements when the queue reaches a fixed size.
- It is efficient enough for fast addition and removal of elements.