Princess Nourah Bint Abdulrahman University
College of Engineering

Telescope inspection and maintenance robot

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Abstract

Radio telescopes are highly sensitive to environmental and structural factors that can significantly affect their accuracy and operational stability. These issues include dust accumulation on the dish surface, corrosion of metal components, and structural misalignment caused by vibrations or harsh weather, which may go undetected with manual inspection, potentially leading to errors in astronomical data or temporary system failure. This project aims to reduce manual inspection, improve fault detection accuracy, speed up maintenance response, and minimize operational errors caused by undetected faults. To achieve these goals, an intelligent automated inspection system was designed using a robotic arm equipped with a high-resolution camera, controlled by a Raspberry Pi 3 B+ unit. The system captures periodic images of key telescope components and compares them to reference images to detect early signs of faults. Although the system has not yet been tested in a real environment, the current design is expected to enhance inspection efficiency and support more reliable telescope performance.

Introduction / Background

Radio telescopes open the skies for us, it helps in understanding the universe especially the Milky Way Galaxy which we live in, it allows us to study celestial objects using the emitted radio signals. It receives signals well regardless of weather conditions, which was a key challenge in optical telescopes. However, constant rains, humidity and winds could impact the accuracy of the radio telescopes, for example:

- Steel structure corrosion.
- Dust accumulation on the telescope’s dish surface.
- The telescope’s dish may be deflected by strong winds.

Therefore, to address the malfunctions that could occur due to the above-mentioned challenges and others, it is necessary to develop a smart solution to detect malfunctions automatically and quickly, reducing the need for manual inspections, which will increase the effectiveness and the efficiency of the telescopes.

Our project aims to design a robotic arm that monitors the telescope periodically. When any malfunction is detected, the robotic arm sends direct alerts to the maintenance team via Wi-Fi.

System Model / Methodology

A 3D robotic arm was designed with a specific range of motion to automatically inspect critical components of the telescope. Motors and an 8MP camera were integrated and connected to a Raspberry Pi, which handles control and processing tasks. Python code was developed to control the arm’s movement, capture images, and analyze the collected data.

To support periodic and automated inspections, reference images were first captured under ideal telescope conditions. Captured images are then processed using Python-based image comparison techniques to detect surface anomalies such as rust, dirt, or misalignment. Upon detecting irregularities, the system sends real-time Wi-Fi alerts and logs all findings automatically.

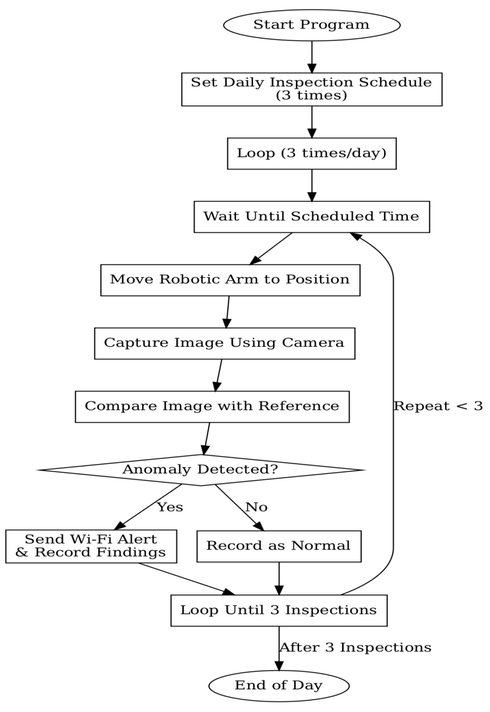


Figure 1. Automated Telescope Inspection Workflow

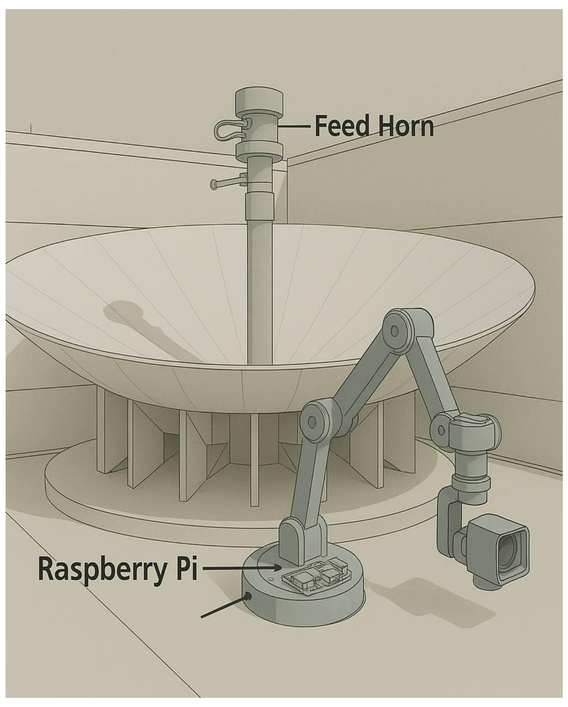


Figure 2. Telescope Inspection Arm Concept

Proposed Solution / Main Idea

The goal of this project is to create an intelligent robotic system that can automatically and continually check the state of astronomical telescopes to discover problems early. The system is built on a robot that is controlled by a Raspberry Pi 3 B+ unit and has a high-resolution camera and a robotic arm.
The system captures images of the telescope’s critical components three times a day. It performs a precise comparison between the captured images and ideal reference images using image processing algorithms developed in Python.
The captured images are compared with the original reference images to detect changes or any of the following problems:
Contamination: Such as the presence of layers of dust or dirt that may affect the telescope's performance.
Rust or corrosion: Changes in the color of metal surfaces or the appearance of spots indicating damage.
A slight shift in some part's positions relative to the reference is known as vibration or anomalous movement. When any of the issues above are identified, the system notifies the main control center via Wi-Fi and includes an image that shows the issue and its position so that it can be fixed.

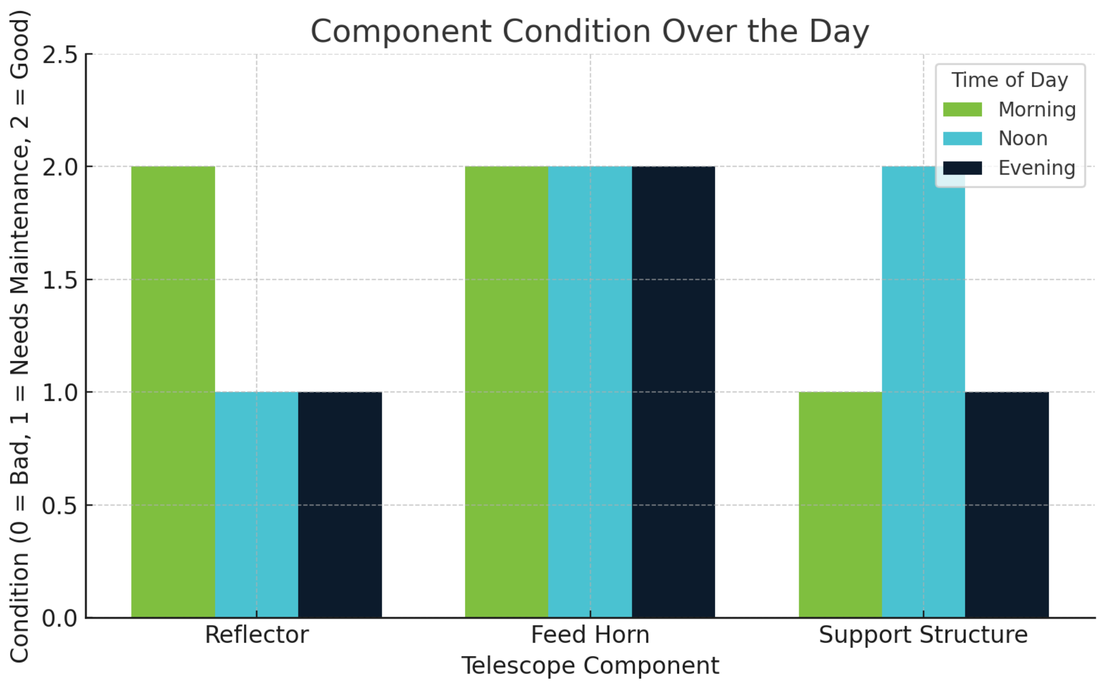


Chart 1. Component Condition Over the Day

Results / Simulation / Discussion

The system uses a robotic arm with an 8MP camera to automatically inspect critical parts of the radio telescope, based on assumptions:

- Up to 90% detection accuracy compared to approximately 70% with manual inspection.
- 40–50% reduction in inspection time, allowing for faster fault identification and real-time alerting.
- Reduced human error via automated robotic movements in repetition.

The framework has yet to be practically evaluated, however, the robotic arm surpassed manual inspection within a 10-cycle simulation both in speed and accuracy. With further development, testing will be conducted soon in order to see the results physically and measure them against the predicted results.

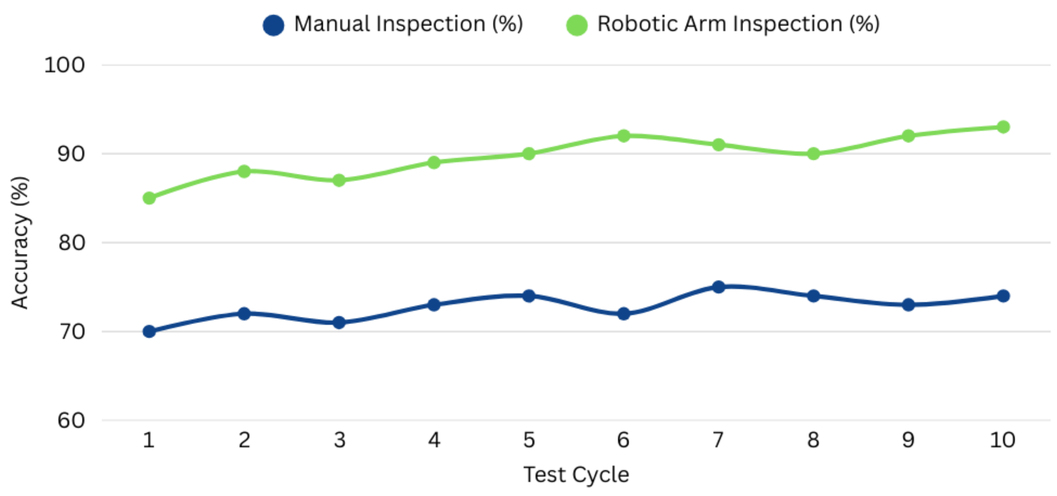


Figure 3. Inspection accuracy (%) over 10 test cycles: robotic vs. manual.

Conclusions

This project represents an important initial step toward developing an intelligent system for the automated inspection of radio telescopes. The system works by detecting issues that indicate faults affecting operational efficiency, including dust accumulation, corrosion, and structural misalignment. By automating the inspection process and providing instant alerts to the control center, the system is expected to reduce reliance on manual procedures, lower the chance of human error, and support faster and more effective maintenance responses. Although the system has not yet been tested in a real environment, the design provides a strong foundation for future development. Upcoming stages may include field testing and further enhancements to ensure its reliability and adaptability to various environmental and operational conditions.

References:

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