

# Mobile Robotic System for Long Term Culvert Inspections Using 3D LiDAR

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## Objective & Motivation

Culvert systems are essential to infrastructure, as they manage water flow and help prevent flooding. However, assessing their condition for maintenance and upkeep is often time-consuming and labor-intensive. Previous studies, such as those by Jeong et al. [1], have explored the potential of 3D LiDAR sensors mounted on mobile robots for tunnel health monitoring. Building on this research, this project seeks to automate the inspection process by integrating a robotic platform equipped with LiDAR and IMU sensors. Using SLAM technology, the system generates detailed point cloud data to create accurate 3D maps of culverts, enabling precise and efficient structural assessments.

## Materials/Hardware

### PackBot 510

The PackBot 510 was selected as the robotic platform for sensor deployment and testing (Figure 1). Its maneuverability enables effective navigation through confined spaces, making it an ideal choice for automating inspection processes in infrastructure maintenance.



Fig .1 : Robotic Platform (PackBot 510)

### 3D LiDAR

LiDAR provides high-resolution spatial data by measuring distances with laser pulses. To streamline the inspection process and generate a detailed 3D map with point cloud points, the Velodyne VLP-16C was chosen due to its ability to provide a 360° horizontal field of view (Figure 2). Its lightweight design and low power consumption make it ideal for integration.



Fig . 2: 3D LiDAR (Velodyne VLP-16C)

### 3DM-GQ7

MicroStrain's 3DM-GQ7 was chosen for its advanced capabilities, featuring an Inertial Measurement Unit (IMU), Real-Time Kinematic (RTK), and GNSS sensors (Figure 3). This dual-function sensor provides highly accurate roll, pitch, and yaw data, as well as precise GPS coordinates.



Fig . 3 : 3DM-GQ7 (IMU/GNSS/RTK)

## Software/Methodology

### Integration

A critical aspect of this project was the integration of 3D LiDAR and IMU sensors to enable precise, real-time mapping. These sensors were integrated using the open-source Robot Operating System (ROS) and the LIO-SAM (LiDAR-Inertial Odometry via Smoothing and Mapping) algorithm to allow accurate localization and mapping. By leveraging sensor communication, the system enhances positional awareness and improves localization accuracy. ROS was employed to ensure seamless data synchronization and processing, while LIO-SAM optimized the fusion of LiDAR and inertial data to generate high-fidelity 3D maps in real time.



Fig . 4 : Entire Robotic Platform

To accommodate all sensors and other necessary equipment, a 3D-printed frame was designed and used to streamline hardware placement on the robot, as seen in Figure 4. In addition to the sensors and processor, batteries were used to ensure that the entire system could function remotely.

### Data Collection and Testing

After successfully integrating the sensors, initial testing was conducted to evaluate their performance in real-world conditions (Figure 5). The primary objective was to generate a high-resolution 3D map of an environment. The LiDAR sensor continuously scanned the surroundings, capturing data points in the form of a dense point cloud, while the IMU provided motion data to enhance positional accuracy. Filtering techniques, such as noise reduction were applied to refine the data. The collected point cloud data was processed using an NVIDIA microprocessor, which handled the demands of real-time mapping.

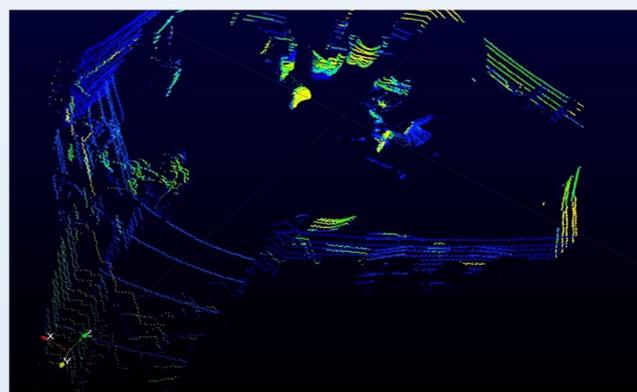


Figure . 5 : Initial Real Time Test

## Results

Testing of the fully integrated sensors on the robotic platform was conducted inside UCF's engineering building, following a route through a hallway and a large atrium. The system generated point cloud data, capturing the building's features and recording moving people for a complete rendering of the area (Figure 6). The LiDAR sensor continuously scanned the surroundings, while the IMU provided real-time motion data, ensuring precise localization. This test validated the system's ability to map dynamic indoor environments accurately.

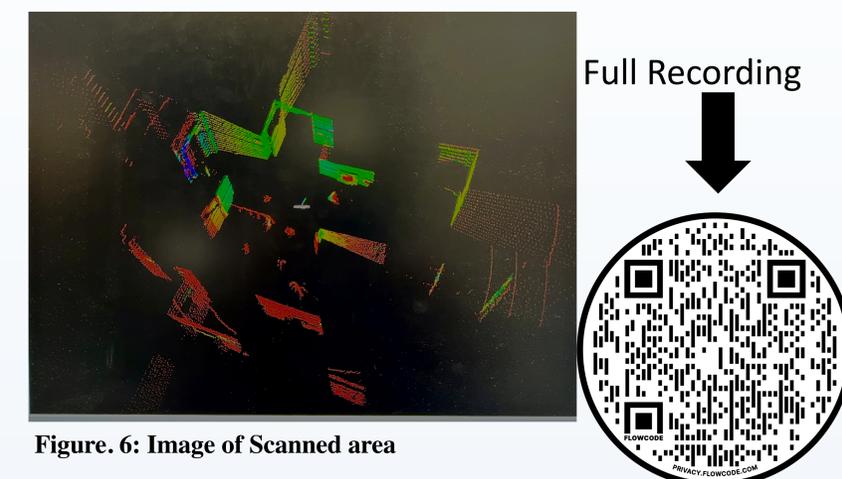


Figure . 6: Image of Scanned area

## Conclusion & Discussion

This project highlights a mobile robot equipped with LiDAR and IMU sensors, utilizing SLAM technology for efficient culvert inspections. Testing is still required in culvert applications to validate the overall aim of this project. Additionally, testing in diverse environments will expand its applications beyond culverts, enabling adaptability to various infrastructure settings. Its capability to generate high-resolution 3D maps makes it valuable for inspecting tunnels, pipelines, and bridges, providing detailed spatial data for structural assessments. This innovation has the potential to revolutionize infrastructure monitoring, reducing costs and improving safety in critical inspection tasks.

## References

- [1] Jeong S, Kim MG, Park J-Y, Oh K-Y. Long-term monitoring method for tunnel structure transformation using a 3D light detection and ranging equipped in a mobile robot. *Structural Health Monitoring*. 2023;22(6):3742-3760. doi:[10.1177/14759217231157237](https://doi.org/10.1177/14759217231157237)