Automated Pipeline Inspection with an Untethered Structured Light Sensing Robot

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Main Objective

- Inspection of transmission pipelines for internal surface damage from corrosion and other operational and environmental conditions.
- Proposes a comprehensive and practical robotic Structured Light (SL) sensing system with enhanced registration and defect estimation solutions for pipeline detection.

The concerned challenges in this work:

- Battery powered remote connection robotic platform for untethered operation.
- Integration of several sensors for localization and reconstruction of pipeline.

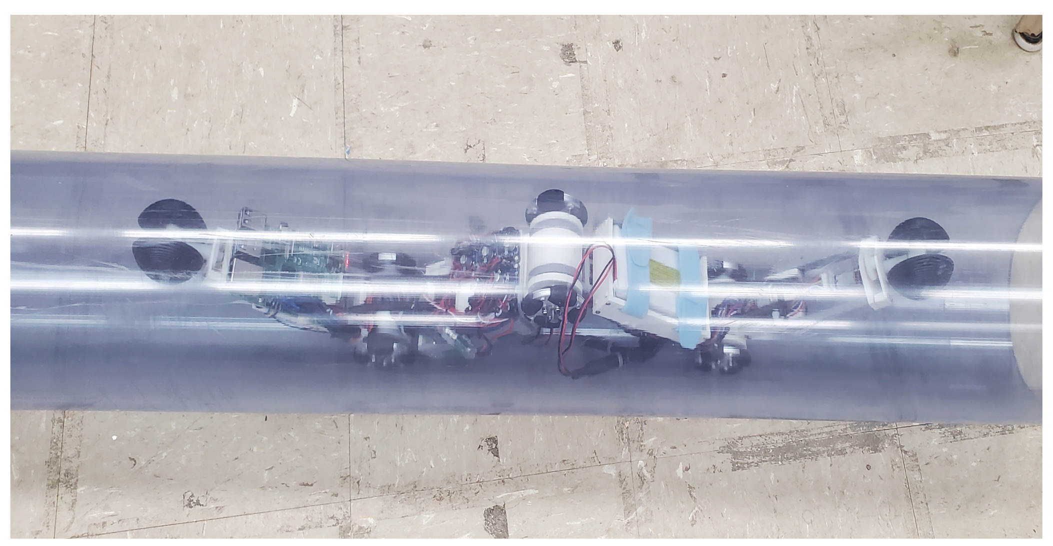

Figure 1. Sensing robot moving in a 6-inch pipe

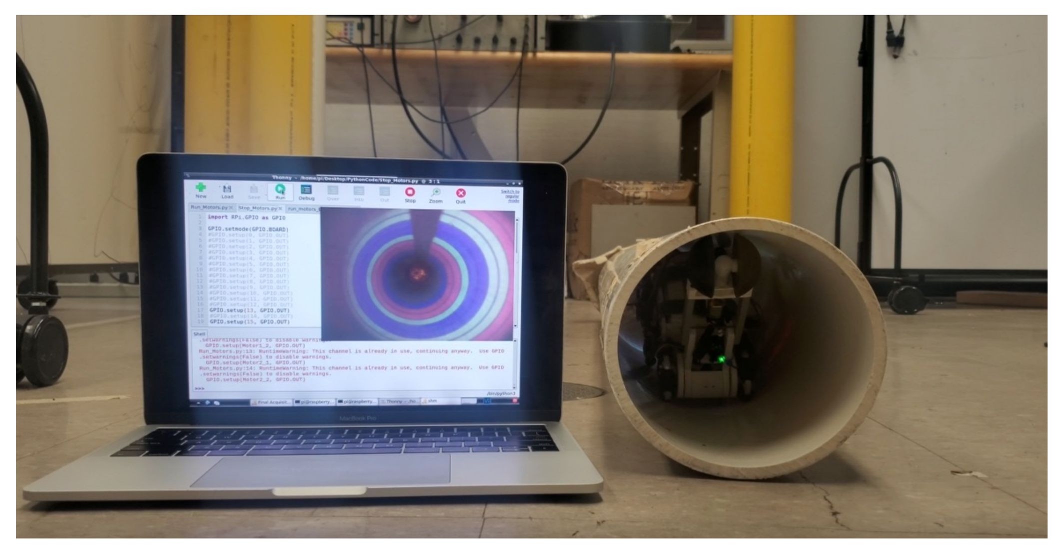

Figure 2. Real-time data collection and monitoring.

Robotic Platform

- Integrated control and acquisition electronics with 14.8V batteries for untethered operation.
- Springs compress robot for taller configuration in larger diameter pipes while stretching to flatter configuration in smaller diameter pipes.
- Wheel encoders for localization and velocity estimation.
- Servo for adjustment of sensor orientation.

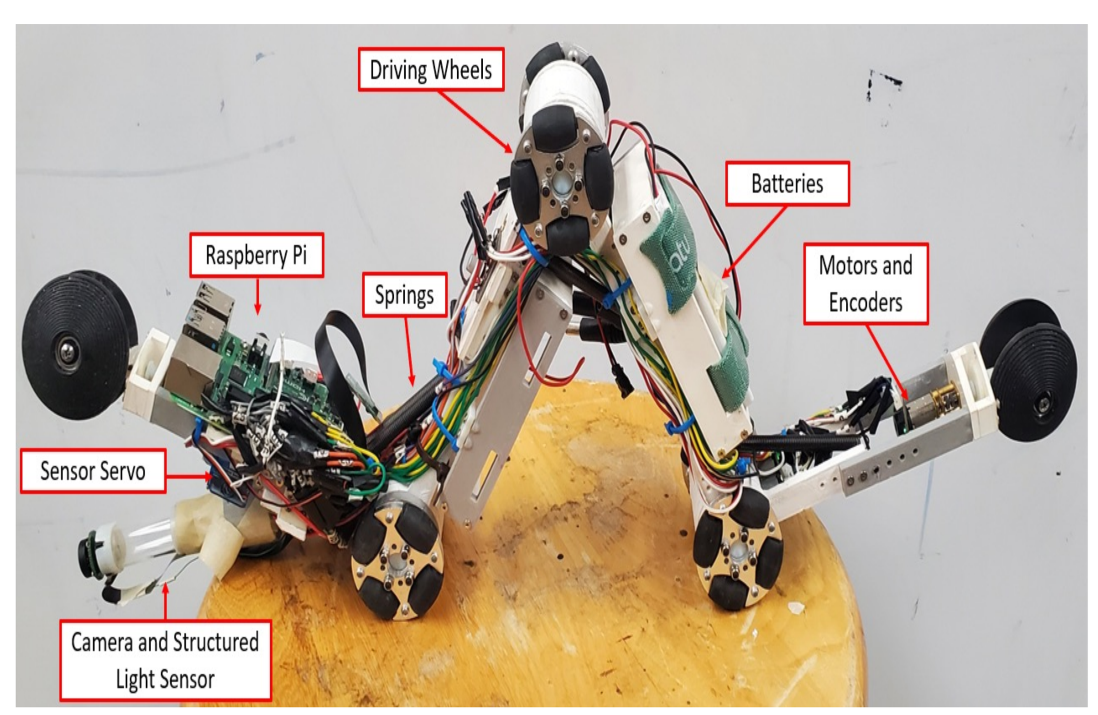

Figure 3. Designed robotic platform.

Structured Light Sensor

- The endoscopic SL sensor consists of camera, slide projector module, and an LED ring.
- A static slide projector is used to project a set of concentric rings and reduce sensor complexity, size, and power consumption.
- The main camera is used to monitor the pipe surface and capture deformations in the projected SL pattern.
- IMU for localization and orientation of the sensor.

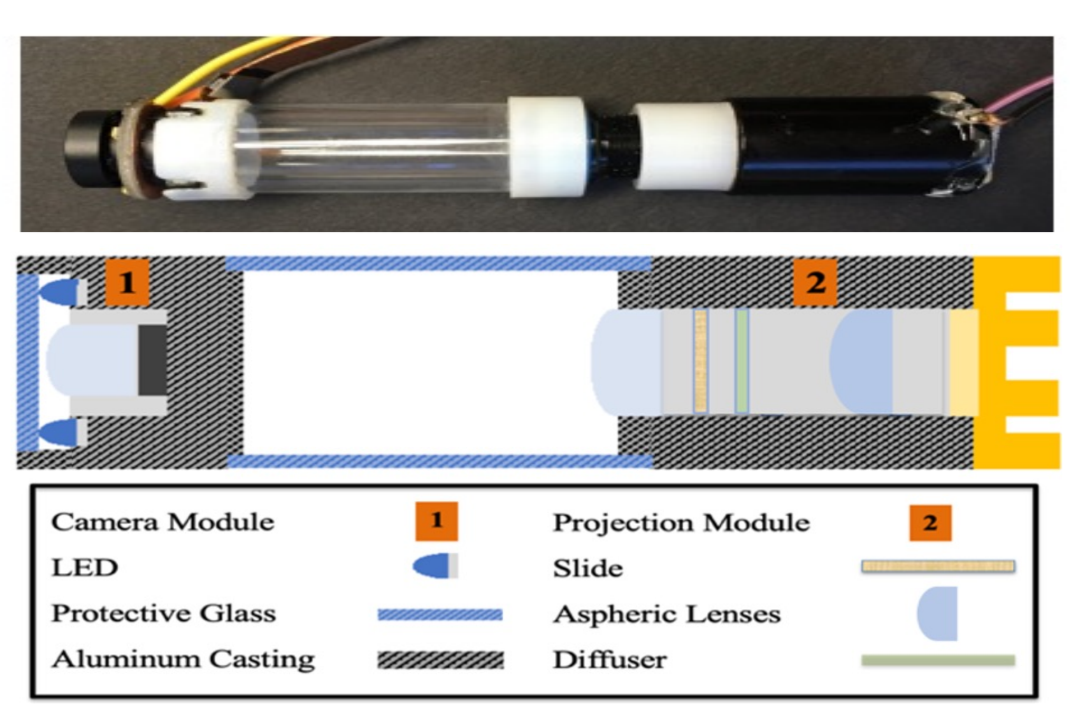

Figure 4. Structured Light Sensor.

Experimental Results

- Capable of moving through different sized pipe (4'' to 8'')

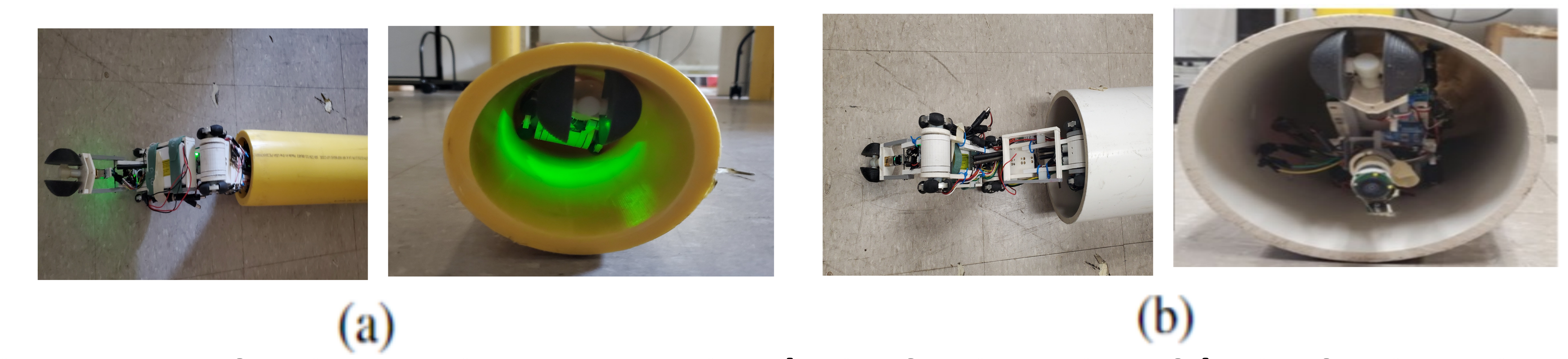

Figure 5. Robotic Sensing system in a) 4inch pipe view b) 6inch pipe view

- Feature-based registration with IMU and robot odometry assisted reconstruction

1. Improves the sensor stabilization process by converting the 3D registration to 2D problem and thus improves the registration robustness.
2. IMU and robot wheel odometry are integrated for correcting the pose of the acquired SL data and estimating the sensor speed.

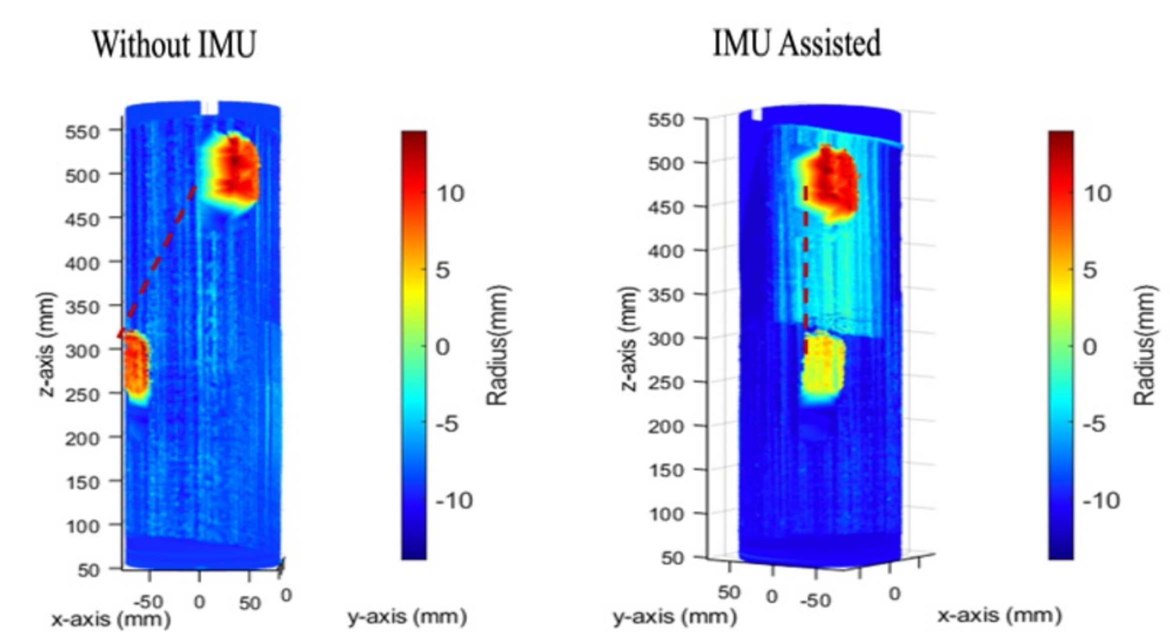

Figure.7. Side view of reconstruction pipe at 25-degree rotation: without IMU (left) and with IMU (right).

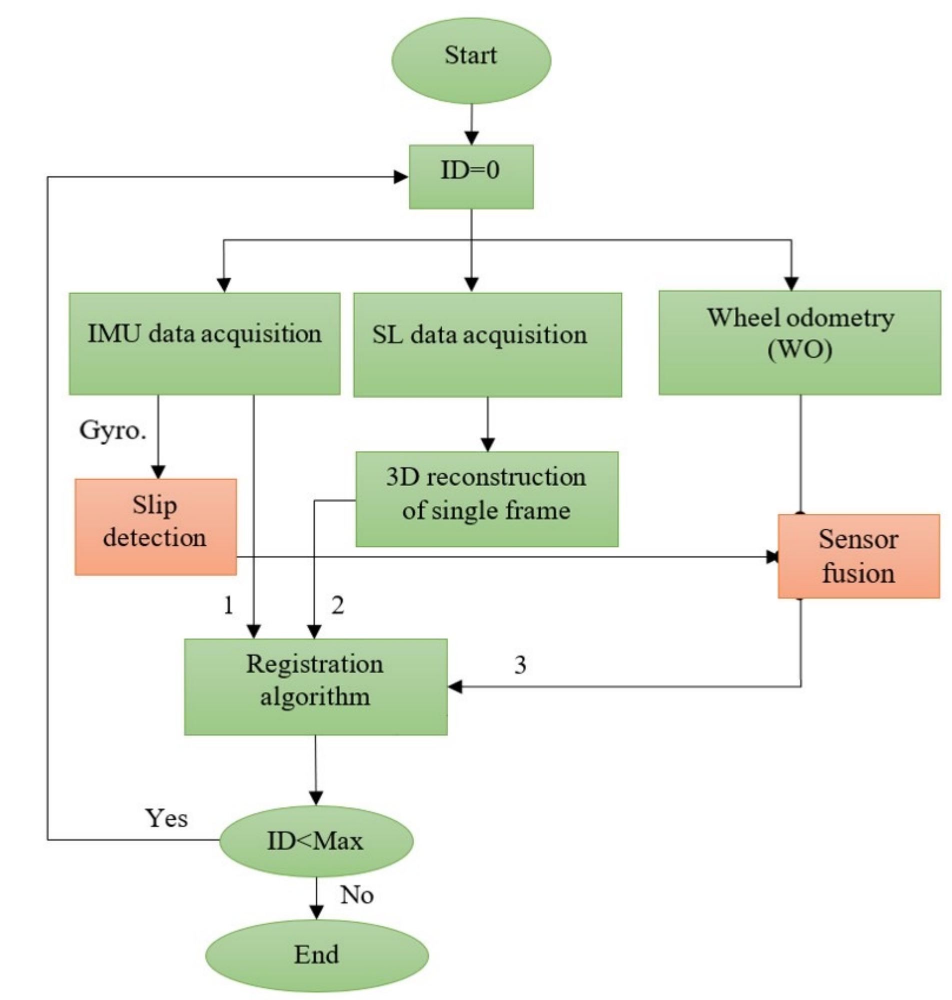

Figure.6. Proposed registration approach for sensor stabilization with data acquisition procedure

- Reconstruction performance with robotic integration on 6'' pipe

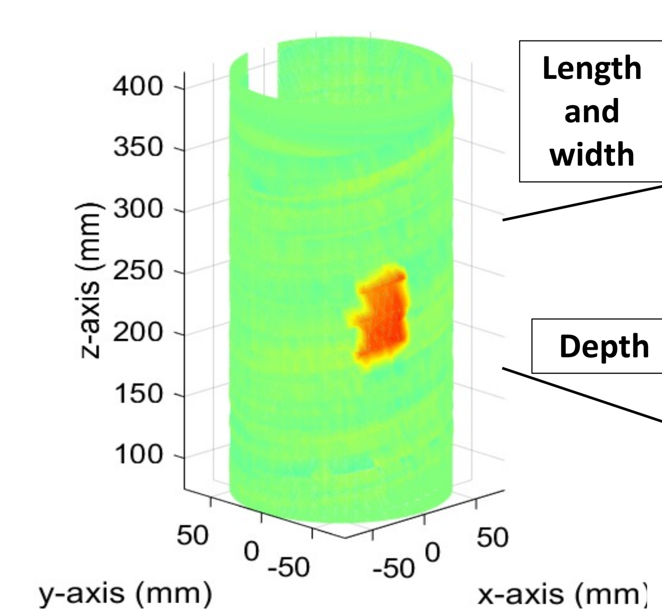

Figure. 8. Reconstruction performance with odometer information from robot

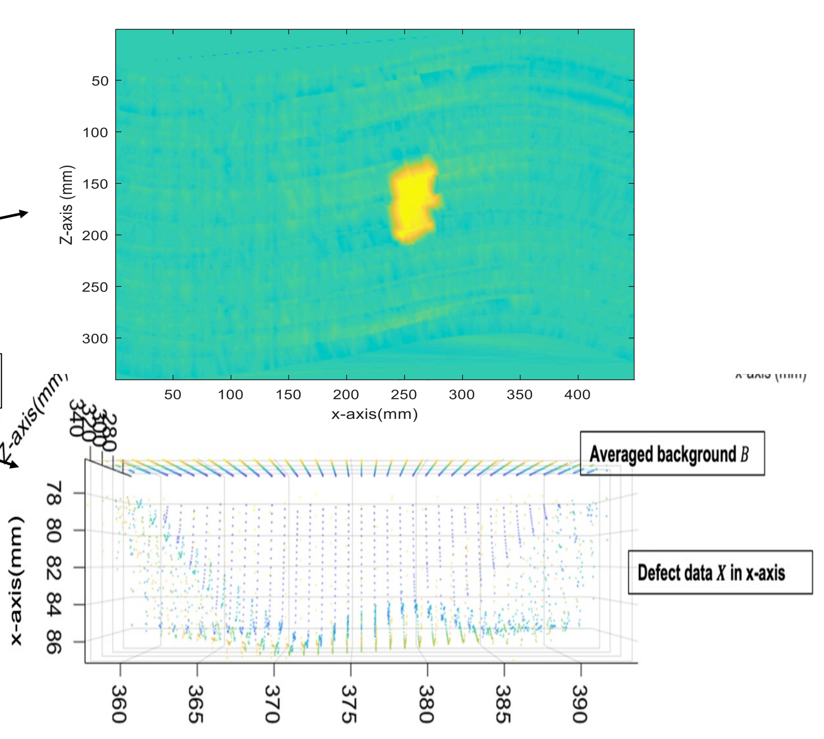

Figure 9. Flattened pipe surface for extracting defect information.

Table.1. Comparison of the Ground VS the estimated defect size from reconstruction

	Length	Width	Depth
Ground Truth (Measured)	70mm	35mm	6mm
Robot Sensing after 6 runs (Estimated)	70.2±4.16 mm	33.7±1.75 mm	6.1±1.22mm

Acknowledgments

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