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Low-Cost, Semi-Autonomous Pipe Inspection Rover for Guatemalan Hydroelrectic Power Plants

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***Abstract*—Water inlet pipes are critical in hydroelectric plants, but prolonged use leads to wear, requiring thorough inspections to identify potential hazard. To address this, a mobile, modular robot has been developed for manual or semi-autonomous pipe inspections. Equipped with LiDAR, depth sensors, RGB cameras, and IMU, the robot scans pipes for damage and accurately locates itself. Its modular design allows for easy assembly and entry through manholes.**

***Index Terms*—Robotics, Industry applications, In-pipe inspection**

I. Introduction

According to the Latin American Energy Organization (OLADE), hydroelectric plants produce 52.3% of Guatemala's total electrical generation [1]. Thus, ensuring the infrastructure's proper condition is crucial to maintaining the production and distribution of power. Furthermore, limitations to regular inspections arise due to extensive subterraneous pipe routes (2-4 km) and few access points. Additionally, human inspections on slippery, confined spaces are inefficient and risky. This work presents a mobile, modular robot capable of manual or semi-autonomous pipe inspections, adapting to diameter changes, slopes, and physical conditions. Manual mode involves joystick control for movement and turning, while semi-autonomous mode automates turning to keep the robot centered. A custom tracked rover equipped with multiple sensors scans pipes for localization, damage and deformation assessment, and stores relevant data for a findings report. The modular design facilitates assembly, transport, and entry through access holes. It comprises of control (computing, sensors) and locomotion/power modules (batteries, motors).

II. Methodology

The robot is equipped with the following sensors for data measurement: a 3D LiDAR (Light Detection and Ranging) with 16 laser light beams, three depth sensors that combine information from an RGB camera with stereoscopic vision technology through two infrared cameras and structured light technology via an infrared projector, an Inertial Measurement Unit (IMU) with 6 degrees of freedom (accelerometer and gyroscope), and two quadrature encoders for accurate movement estimation. Each vision sensor has been strategically positioned and oriented to optimize its field of view, enabling the detection of potential damage and wear within the pipe structure, as well as precise localization of the robot inside the pipe. The LiDAR sensor is positioned at the front with a 45-degree orientation, while the two depth sensors are placed on the sides (right and left) and one at the front, as shown in Fig. 1.

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Fig. 1. Side and frontal view of the robot.

For the inspection, the LiDAR sensor performs a 360-degree sweep to obtain 16 rings, which spatially reconstruct the circumference of the pipe. This information is utilized to determine its ovality percentage [2]. The two lateral depth sensors are employed to reconstruct a section of the pipeline, aiming to visually identify any imperfections while also conducting specific measurements at each joint connecting the pipeline segments. The data from the front depth sensor, combined with information from LiDAR, IMU, and the two quadrature encoders, is utilized to locate the robot within the pipeline using simultaneous localization and mapping (SLAM) techniques.

III. Results and Conclusions

The rover portrayed on Fig. 1 was designed, built, tested and deployed to conduct a successful inspection in the pipes of a hydroelectric power plant in Guatemala, performing a segment reconstruction of the pipe leading to multiple relevant measurements of distance between segments as shown in Fig. 2. Using depth sensors in tandem with LIDAR technology permits accurate measurement of relevant distances, as well as circumference deformation while substantially reducing human risk, thus allowing for more thorough, regular inspections.

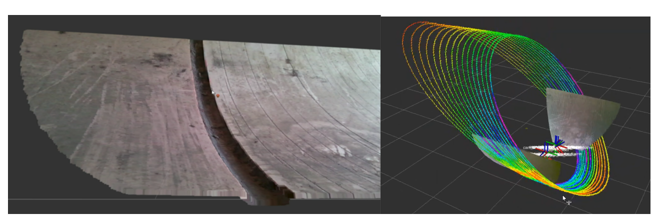

Fig. 2. Partial pipe segment reconstruction

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References

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