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Design and Construction of Unmanned Surface Vessel for Toxic Gas Monitoring in Sewer Pipes Using Lab View

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ABSTRACT: This paper presents the development of an Unmanned Surface Vessel (USV) for monitoring toxic gases within sewer pipes, utilizing LabVIEW for control. Detection of toxic gases in sewer systems is crucial due to potential health and environmental hazards. Traditional inspection methods are labour-intensive and risky. USVs offer a safer alternative. The research aims to design a USV capable of navigating through sewer pipes while detecting toxic gases.

The USV design prioritizes compactness, manoeuvrability, and durability for effective navigation in confined spaces. LabVIEW is employed for real-time control and sensor data processing. Detailed specifications of the USV, including dimensions, propulsion, and sensor integration, are provided. The electrical system, power supply, motors, and gas sensors are outlined alongside LabVIEW implementation.

The design section elaborates on mechanical and electrical aspects, including hull design, frame construction, propulsion, and sensor integration. Experimental results demonstrate the feasibility of the developed USV for toxic gas monitoring in sewer pipes. Discussion emphasizes implications for sewer pipe inspection and USV potential in environmental monitoring. The paper underscores the significance of the developed USV in advancing inspection methodologies, suggesting future research directions.

KEYWORDS: My Rio, LabVIEW, DAQ, USV, PVC, GUI

I. INTRODUCTION

Monitoring toxic gases within sewer pipes is critical for ensuring public health and environmental safety. Sewer systems, essential for waste management in urban areas, can harbour harmful gases such as hydrogen sulphide, methane, and ammonia, which pose significant risks to both human health and the ecosystem. Traditional methods of inspecting sewer pipes, often involving manual labor and physical entry into hazardous environments, present inherent dangers to personnel and are inefficient in detecting potential hazards. Given these challenges, there is a growing need for innovative solutions that can enhance the safety and efficiency of sewer pipe inspection processes. Unmanned Surface Vessels (USVs) present a promising alternative, offering the capability to navigate through narrow sewer pipes autonomously while conducting comprehensive gas monitoring tasks. By employing USVs for this purpose, it becomes possible to mitigate risks to human workers and improve the accuracy and coverage of gas detection efforts.

This research endeavors to address this need by designing and constructing a specialized USV tailored for toxic gas monitoring within sewer pipes. Leveraging LabVIEW as the control framework, the USV is equipped with sensors capable of detecting and quantifying various toxic gases commonly found in sewer environments. The integration of LabVIEW enables real-time control of the USV's movements and facilitates the processing and analysis of sensor data, allowing for timely detection and response to potential gas leaks or hazards. This paper aims to provide a comprehensive overview of the design, construction, and implementation of the USV for toxic gas monitoring in sewer pipes. By introducing this innovative approach, we seek to improve the effectiveness and safety of sewer pipe inspection processes, ultimately contributing to the protection of public health and the environment. Through this research, we hope to demonstrate the feasibility and potential impact of employing USVs in environmental monitoring

applications, paving the way for future advancements in this field. Ensure that you return to the 'Els-body-text' style, the style that you will mainly be using for large blocks of text, when you have completed your bulleted list.

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II. RELATED WORK

Bathymetry measurements are needed in shallow, near-shore environments to estimate the potential distribution of macroalgae and seagrass, which contribute to oceanic carbon sinks in Greenland and other Arctic locations. Additionally, ocean current observations near icebergs and marine-terminating glaciers are necessary to estimate their melt rates. Rocky coastlines, icebergs and glaciers, however. The Arctic Research Centre Autonomous Boat (ARCAB) is a student-built ASV that can be transported on a euro-pallet and operated from a small boat and from shore.

Stepper motors are one of the most indispensable entities of any industrial sector, be it the process industries or the manufacturing industries. Existing stepper motors are programmed through microprocessors, controllers and electrical circuits. LabVIEW a software pioneered by National Instruments has also been used to program them, called as NI-my.

This research effort aims at investigating alternative real-time implementation software and hardware for Guidance, Navigation and Control (GNC) algorithms for an Unmanned Ground Vehicle (UGV). A GNC algorithm was previously developed for a skid-steered tracked UGV to go through assigned waypoints based on encoder counts. The UGV has two electric motors driving the tracks on each side and two encoders providing the speeds of the drive wheels.

The paper "Modelling and design of a drain cleaning robot" presents an interdisciplinary approach to designing a specialized robot for drain cleaning applications. It emphasizes practicality, focusing on real-world challenges in sanitation and infrastructure maintenance. The inclusion of "modelling" suggests a strong emphasis on theoretical frameworks, likely involving mathematical and predictive modeling. Design considerations likely include maneuverability in tight spaces, resistance to corrosion, and efficiency in removing debris. The paper demonstrates innovation in robotics applications, offering potential solutions to critical infrastructure maintenance issues.

"Low-Cost Data Acquisition for Autonomous Vehicle," addresses the critical need for affordable yet effective data acquisition systems in the realm of autonomous vehicles. The emphasis on cost underscores a practical approach to democratizing technology and fostering widespread adoption. The thesis likely explores innovative methods or technologies to achieve this goal, potentially leveraging open-source platforms or repurposing existing hardware for data collection. By focusing on affordability, the research aims to lower barriers to entry for autonomous vehicle development, thereby accelerating progress in this rapidly evolving field.

III. METHODOLOGY

The methodology section outlines the systematic approach followed in designing, constructing, and testing the Unmanned Surface Vessel (USV) for toxic gas monitoring in sewer pipes using LabVIEW on the NI my RIO platform. The following steps were undertaken to ensure the successful development and validation of the USV system:

1. **Requirements Analysis:** The initial phase involved a comprehensive analysis of the requirements for the USV system, including operational objectives, environmental constraints, and technical specifications. Stakeholder consultations and literature reviews informed the identification of key system requirements.
2. **Conceptual Design:** Based on the identified requirements, conceptual designs of the USV's mechanical, electrical, and software components were developed. Considerations were made for compactness, manoeuvrability, and sensor integration, ensuring compatibility with sewer pipe environments.
3. **Material Selection:** Selection of appropriate materials for the USV's hull, propulsion system, sensors, and electrical components was conducted based on factors such as durability, corrosion resistance, and weight considerations. PVC was chosen for the hull due to its lightweight and corrosion-resistant properties.
4. **Sensor Calibration:** Gas sensors integrated into the USV underwent calibration procedures to ensure accurate and reliable measurements of toxic gas concentrations. Calibration curves were generated using standard gas concentrations to correlate sensor output to gas concentration levels.

5. **LabVIEW Programming:** LabVIEW software was employed to develop custom programs for controlling the USV's movements, acquiring sensor data, and processing data in real-time. Graphical user interfaces (GUIs) were designed to provide intuitive controls for remote operation and visualization of sensor readings.
6. **Testing and Validation:** The constructed USV underwent rigorous testing in controlled laboratory environments and simulated sewer conditions to evaluate performance and reliability. Validation tests included manoeuvrability assessments, gas detection trials, and endurance tests to verify operational capabilities and adherence to design specifications.
7. **Iterative Optimization:** Based on testing feedback and performance evaluations, iterative refinements were made to the USV's design, software algorithms, and operational procedures to enhance functionality and address any identified shortcomings.

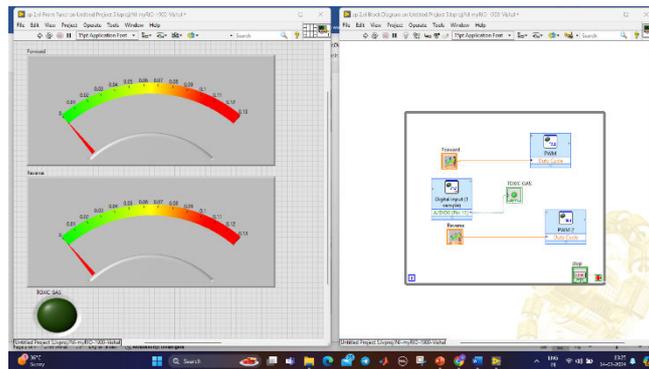


Fig.5. LabVIEW GUI

IV. EXPERIMENTAL RESULTS

Experimental trials confirmed the Unmanned Surface Vessel's (USV) remarkable manoeuvrability in simulated sewer environments, adeptly navigating narrow passages and circumventing obstacles. Gas detection trials validated the USV's capability to detect and quantify toxic gases like hydrogen sulphide (H₂S), methane (CH₄), and ammonia (NH₃) in real-time, enabling proactive hazard response. Endurance testing demonstrated sustained performance over extended missions, supported by a rechargeable lithium-ion battery pack. LabVIEW-based data visualization facilitated intuitive remote operation and analysis of sensor data, revealing gas concentration trends. The USV exhibited high reliability and robustness, promising effective deployment in sewer infrastructure management for leak detection and environmental risk assessment.



Fig.6. Outcome Photograph

V. CONCLUSION

In conclusion, this research presents the successful development of an Unmanned Surface Vessel (USV) tailored for monitoring toxic gases within sewer pipes. By leveraging LabVIEW for control and sensor data processing, the USV offers a safer and more efficient alternative to traditional inspection methods. The compact design, coupled with robust propulsion and sensor integration, ensures effective navigation in confined sewer environments.

The experimental results validate the feasibility of the developed USV, demonstrating its capability to detect toxic gases in real-time while navigating through sewer pipes. The implications of this research extend beyond sewer pipe inspection, highlighting the potential of USVs in environmental monitoring applications.

Moving forward, further research could explore enhancements to the USV's capabilities, such as autonomous navigation algorithms, additional sensor modalities for comprehensive environmental monitoring, and integration with cloud-based data analytics platforms. Overall, the developed USV represents a significant advancement in inspection methodologies, promising safer and more efficient monitoring of toxic gases in sewer systems.

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