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Design of Prototype of Robot to Detect Cracks in Multi Shape Pipeline Systems

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ABSTRACT: Pipeline infrastructure plays a critical role in transporting essential resources such as water, oil, and gas. However, regular maintenance and inspection of these pipelines are required to ensuring their integrity and preventing failures that could lead to environmental disasters, economic losses, and safety hazards. To address the limitations of traditional pipeline inspection methods, this project proposes the development of an automated pipeline inspection robot which is designed to improve the accuracy, safety, and efficiency of pipeline monitoring. The robot leverages advanced technologies such as Arduino microcontrollers, Bluetooth communication, DC motors, and infrared (IR) sensors to automatically inspect the pipeline infrastructure and detect structural anomalies. The system is equipped with 100 RPM DC motors, which enable agile movement through narrow pipelines, and an L293D motor driver for precise control of the robot's motion. By integrating IR sensors, the robot can effectively detect cracks, leaks, and other defects on the surface of pipelines with high accuracy. The proposed inspection robot operates with remote control, reducing the need for human intervention and minimizing the risks faced by workers in hazardous environments. The developed prototype can send real-time data to an external device in remote, enabling continuous monitoring of the pipeline's condition and further action in limited time.

I. INTRODUCTION

The existing systems for pipeline inspection primarily rely on manual methods, Even with the aid of NDT technologies, human oversight play sacrificial role in interpreting the data, and minor anomalies might go unnoticed, leading to undetected pipeline weaknesses. As a result, some defects may not be identified early enough, leading to pipeline failures, leaks, or ruptures that can cause environmental damage, costly repairs, or even accidents. In response to these limitations, there is a growing need for automated solutions that can streamline the inspection process while enhancing accuracy and safety. The robot's ability to autonomously navigate through pipelines and perform inspections minimizes human involvement, reducing both the risk to workers and the time required for the inspection process. By leveraging modern technologies, this system aims to revolutionize pipeline inspection by making it faster, more accurate, and safer, ultimately contributing to more reliable pipeline maintenance and reducing the likelihood of costly and hazardous failures.

II. RELATED WORK

In [1] authors project aims to reduce the chances of accidents by creating a simple innovative vessel monitoring system using multiple sensors and microcontrollers. The system displays the vessel’s current condition to the ship crew and passengers using an alert system that involved buzzers and flashing LEDs as well as uploading the current location of the vessel to a secure server in case of contingencies. This have been achieved by the module unit consists of the node MCU and Arduino Uno, where all sensor inputs are simultaneously processed in both units and via an inbuilt display that is governed by Arduino Uno, the individual in control can monitor the vessel’s system and command any actions necessary. In the case of abnormalities, like if the temperature exceeds standard set limits, the controller perceives it and initiates two sets of alerts depending on severity to all passengers onboard. If the limit exceeded, then a blinking LED will appear. Moreover, if the second limit is surpassed a buzzer will constantly be on until the situation is under control. Overall, the project implemented an IOT module using ARDUINO effectively. [3]. the paper illustrates a novel approach for safe maritime sailing by emphasizing on three core aspects that include: overweight detection and obstacle avoidance as well as embedded GPS tracking system. Automation and accident prevention are done using PID

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controller by fine tuning through several trial and errors. For it to be autonomous, PID controller is used taking into account the vessel's current and prior locations using the GPS module to measure its deviation from course and return it to its original desired path. For overweight detection, the circuit involved 4 transistors acting as switch reutilizing the conducting property of impure water, that were positioned to indicate two levels of warnings being warning and danger level. Sensing high level of water due to overload, will initiate a signal to the control room via an A7 Ai-Thinker module to act depending the on the type of warning. Moreover, to prevent obstacles, ultrasonic radar was built using JSN SR04T ultrasonic sensor on top of a servo arm with two HC-SR04ultrasonic sensors on the flanks to enhance the angle and range of detection.

In [4] The paper emphasizes how the internet of things technology, and the Global positioning system (GPS) can be utilized for water border safety. The purpose of the idea is to give an alert signal if an unidentified vehicle/vessel is close to the known border. The alert signal differs by the distance of closeness of the unidentified vehicle is to that known border of TamilNadu . Basically, the idea was adapted in order to save the lives to Indian fishermen, fishing near the India-Sri Lanka oceanic outskirt. This paper tackles that issue, by creating an advanced GPS boundary detection and alert system via IoT. Furthermore, when it comes to the design of the system the GPS will gather the scope and longitude of the location of the fishermen and send it to a microcontroller unit. The system will check where the vessel is in terms of the border and gives an alert if it is located outside the border outskirt using IoT. The microcontroller will be used to save the location in terms of longitude and scope and then transmits a signal either to the vessel command or nearby marine patrol to guide them to the exact location. The message will be displayed on the vessel's LCD command screen.

III. PROPOSED ALGORITHM

This robot is engineered to autonomously navigate through pipelines, detect cracks and leaks, and provide real-time data to operators, thereby minimizing human intervention. The core of the system is the Arduino microcontroller, which serves as theprimarycontrolunit.Itmanagestherobot'smovementandcommunicationfunctions, ensuring that the system operates smoothly and efficiently. The robot is equipped with 100 RPM DC motors that enable it to move with precision and agility through confined pipeline spaces. An L293D motor driver is used to control these motors, allowing for smooth and accurate operation, even in tight or curved sections of the pipeline. The key innovation of this system lies in its use of infrared (IR) sensors for defect detection. These sensors are capable of identifying surface cracks, leaks, and other structural anomalies with high accuracy. As the robot traverses the pipeline, the IR sensors continuously scan the internal surfaces for defects, sending real-time data to the Arduino for processing. If a defect is detected, the robot can alert the operator via Bluetooth communication, providing timely information that enables immediate maintenance actions. The integration of Bluetooth communication allows for real-time remote monitoring, which is a significant improvement over traditional inspection methods. The robot can transmit data to an external device, such as a smart phone or computer, enabling operators to monitor the pipeline's condition from a safe distance. This eliminates the need for manual inspections in hazardous or inaccessible areas, significantly enhancing worker safety. Additionally, real-time feedback ensures that any defects are identified and addressed promptly, reducing the risk of pipeline failures.

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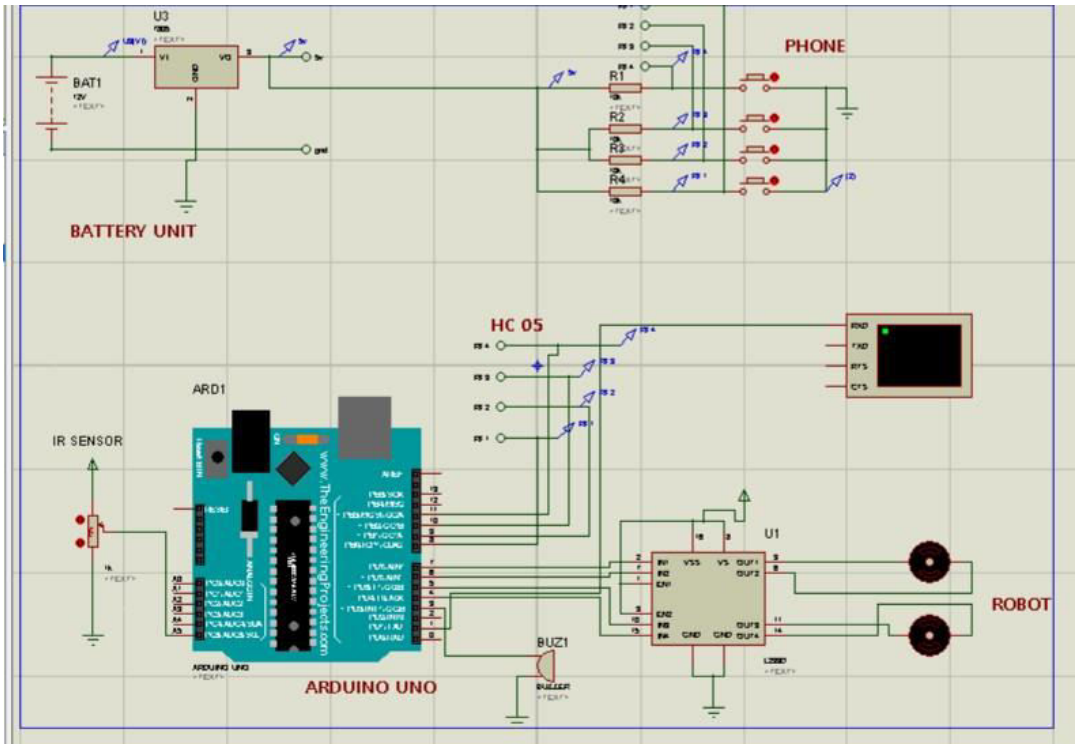
IV. SIMULATION RESULTS



CIRCUIT SCHEMATIC DIAGRAM

V. CONCLUSION AND FUTURE WORK

The development of an automated pipeline inspection robot presents a transformative solution to the challenges posed by traditional manual inspection methods. By integrating modern technologies such as Arduino control, infrared (IR) sensors, Bluetooth communication, and DC motor-driven mobility, this system significantly enhances the accuracy, efficiency, and safety of pipeline inspections. It autonomously navigates pipelines, detects structural defects in real-time, and transmits data to operators remotely, minimizing the need for human intervention. In conclusion, this automated robot provides a cutting-edge solution for maintaining the integrity of pipeline infrastructure. By enabling early detection of defects and streamlining the inspection process, it not only prevents potential failures and environmental hazards so improves overall pipeline management.

In the future, several enhancement scan be made to the proposed automated pipeline inspection robot to further improve its functionality and adaptability. One potential area of improvement is the integration of advanced sensors, such as ultrasonic or electromagnetic sensors, which can detect internal defect sand corrosion, providing a more comprehensive assessment of pipeline health. Combining these sensors with the existing infrared (IR) technology would enhance the robot's ability to detect both surface and sub surface anomalies.

Another avenue for future work is the development of more sophisticated algorithms for data analysis and defect classification. Machine learning techniques could be in corporated to enable the system to learn from previous inspections and improve its accuracy in identifying defects. Additionally, artificial intelligence (AI) could be used to predict potential pipeline failures based on historical data, allowing for preventive maintenance.

Expandingtherobot'sautonomyandnavigationcapabilitiesisanotherkeyareaforimprovement. The integration of GPS and advanced navigation algorithms would allow the robot to operate in more complex pipeline networks, including underwater or under ground pipelines.

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Finally, making the robot more robust and adaptable to various pipeline diameter sand materials will improve its versatility, enabling it to inspect a wider range of pipelines across different industries and environments.

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