An-Najah National University

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Department of Computer Engineering

Graduation Project II

PipeDetective

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Disclaimer

This report was accomplished by Marah Sha'bello and Raghad Dabbous at the Computer Engineering Department, Faculty of Engineering, An-Najah National University. The views expressed in this report are sole of the authors' own and do not reflect the view of An-Najah National University, Department of Computer Engineering.

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Abstract

Workers face many challenges in their daily work when they deal with pipes and narrow places, as well as humans cannot enter to check if there are any problems.

PipeDetective robot has been designed to pass through narrow places and video stream the process, then use image processing to detect the cracks. PipeDetective can move in auto mode or manual mode by controlling it remotely. By using this robot, the detection process becomes more efficient, reduces human errors, and increases productivity.

First Chapter

1. Introduction

1.1 Problem Statement

Workers in industries that deal with pipes and narrow spaces face numerous challenges in their daily work, particularly when it comes to detecting cracks in pipes. The limited accessibility of these confined areas often makes it difficult to inspect pipes thoroughly and efficiently. Furthermore, real-time monitoring of crack detection poses another significant challenge. To address these issues, this hardware graduation project aims to develop an automated system that can detect cracks in pipes.

1.2 Objectives

The primary objective of this project is to design and implement a crack detection system that overcomes the challenges faced by workers when dealing with pipes and narrow spaces. The system should be cost-effective, efficient, and user-friendly.

1.3 Scope of the work

This project is intended for workers who are involved in the detection of cracks in pipes.

1.4 Significance of the work

The significance of this project lies in its ability to detect cracks in pipes, benefiting workers in various industries. By providing a portable and automated solution, the system improves the efficiency and accuracy of crack detection, reducing the need for manual inspections and minimizing human error. The integration of real-time monitoring and video streaming capabilities enhances the safety and productivity of workers, enabling them to make informed decisions and take timely actions.

1.5 Report Organization

Chapter 1: An introduction and overview.

Chapter 2: Shows the problems and constraints that have occurred in this project, also it shows the previous courses that helped develop this project.

Chapter 3: Literature Review.

Chapter 4: Methodology which includes Overview of the system, System design and components.

Chapter 5: Results and Discussion.

Chapter 6: Conclusion and Recommendations.

Chapter 7: Future work.

Second Chapter

2. Constraints and Earlier Coursework

2.1 Constraints and limitations

2.1.1 Design Difficulty

Choosing the appropriate design was a challenge due to size constraints, as it needs to navigate narrow spaces and fit within confined areas. Also translating the design into a physical object using 3D printing technology introduced complexities as we had to ensure that the design could be accurately translated into 3D printed parts while still meeting size requirements and maintaining structural integrity.

2.1.2 Electrical components sensitivity

In the field of electrical components, dealing with small components such as drivers and chips is challenging due to their sensitivity to voltage and current.

2.1.3 Batteries

In the beginning, lithium batteries were used, but they caused extra weight on the robot, so the mass became not properly distributed on the robot, so the lithium batteries were replaced with an adapter.

2.1.4 Camera

Esp32-cam drops streaming after a while, which causes the cracks to not be detected sometimes.

2.1.5 Time limit

To build this project various stages will be required including the selection of the best design, component procurement, and integration. These stages require adequate time for research, analysis, and decision-making. Delays in component delivery were also a challenge.

2.2 Earlier Coursework

Building our application more efficiently and effectively was made easier by gaining information from university courses such as Microcontrollers, Microcontrollers Lab, CPU Lap, Microprocessors, Electronic circuits and Critical Thinking.

Third Chapter

3. Literature Review

The purpose of this paper was to discuss how cracks in pipes are detected using robots. The first step was to choose the appropriate design. To do this we read a paper reviewing wheeled robots for pipe inspection." The wheeled In-Pipe Inspection Robots can pass through horizontal, vertical, inclined, curved, branched and varying diameter pipelines. It has high mobility, a simple mechanism, less traction, is easy to back drive, and is lighter and smaller. The three-wheeled wall-pressed In-Pipe Inspection Robots are the best suitable for passing through pipelines in terms of payload, mechanism and steering through branched pipes. "[1].

In order to identify the most suitable image processing algorithm to use, we reviewed a paper that said "Image processing technique using Canny detection algorithm can detect edges or lines indicating cracks inside the pipe and processed the images separation to produce a different image by only displaying detected cracks. "[2].

Fourth Chapter

4. Methodology

4.1 Overview of the system

The system comprises a set of nine mechanical components that collaboratively facilitate the robot's movement while effectively leveraging their respective functionalities, ensuring proper operation and performance.

4.2 System Design

The robot is designed for seamless motion within narrow pipe systems. Its body, constructed using lightweight yet robust materials such as carbon fiber PLA, ensures maximum strength without compromising its compact form.

The robot is equipped with a camera and sensor for distance measurements.

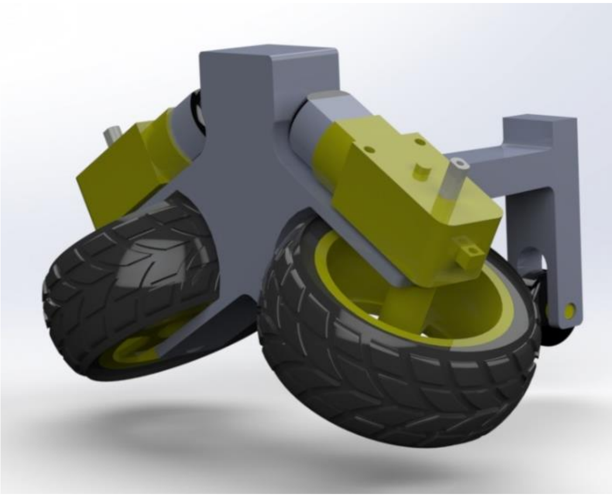

Figure 1: Robot’s Front Design

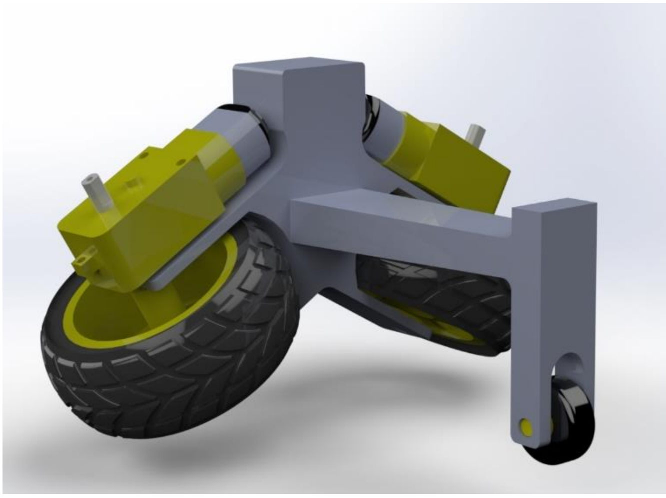

Figure 2: Robot’s Back Design

4.3 Hardware Components

To demonstrate the entire process of the project's development and the tools utilized are discussed in this section.

1. Arduino Nano Microcontroller

Arduino Nano is a compact and versatile microcontroller board based on the ATmega328P microcontroller. It features digital and analog input/output pins. It has a compact size suitable for the robot and pipes size.

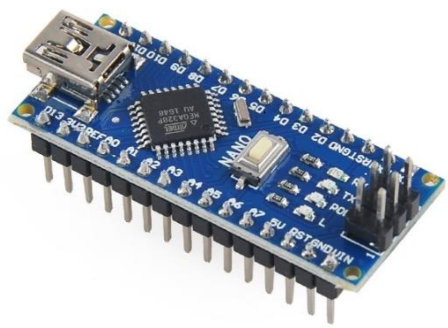

Figure 3: Arduino Nano Microcontroller

2. Wires

In PipeDetective robot, Male-to-Male, Male-to-Female, and Female-to-Female jumper wires were used to establish connections between different electronic components.

Figure 4: Male-to-Male jumper wires

Figure 5: Male-to-Female jumper wires

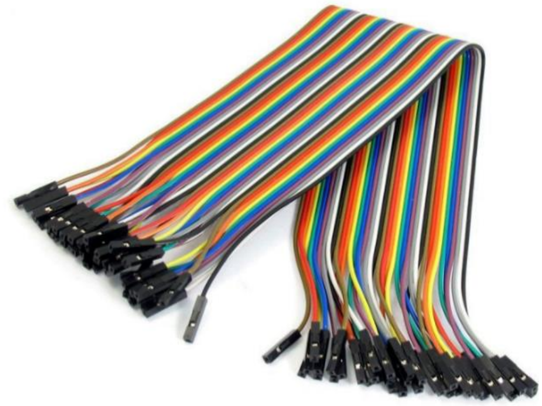

Figure 6: Female-to-Female jumpers wires

3. L298N Motor Driver (H-Bridge)

The L298N Motor Driver played a crucial role in the robot's motion control system, as it facilitated the connection between two DC motors and the wheels. By utilizing the L298N Motor Driver, the speed and direction of the motors are controlled.

The motor driver received input signals from the Arduino nano microcontroller and provided the necessary power and current to the DC motors from the lithium battery.

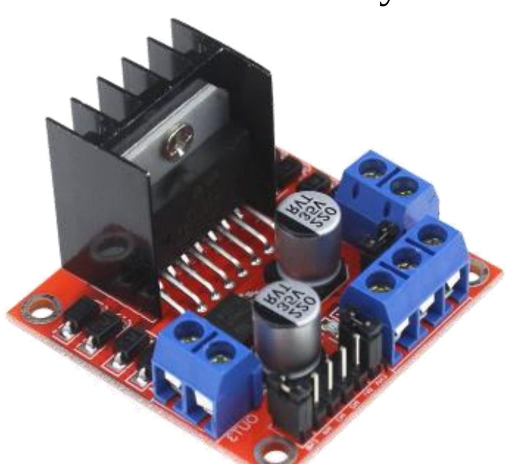

Figure 7: L298N Motor Driver

4. DC Motors and Wheels

PipeDetective robot's movement was controlled by two DC motors connected with two wheels. These motors played a pivotal role in the robot's movement and in determining its direction. By controlling the speed and rotation of each motor, the robot was able to achieve precise movements such as forward, backward, right, and left.

Figure 8: Wheel connected with DC motor

5. Caster Wheel

In addition to the two main wheels connected to the DC motors, PipeDetective robot incorporated a caster wheel as a third wheel, serving as a follower wheel. The caster wheel, typically mounted at the back of the robot, provided stability and support to the overall motion system.

Figure 9: Caster Wheel

6. ESP32-CAM

The ESP32-CAM is a compact development board integrating the ESP32 microcontroller and a camera module for visual data processing. The board enables image capture, video streaming, and wireless communication.

In the PipeDetective robot, the ESP32-CAM is used for video streaming inside the pipe for crack detection using image processing.

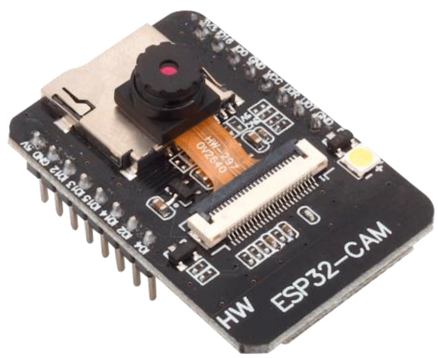

Figure 10: ESP32-CAM

7. Ultrasonic sensor

Ultrasonic is a non-contact sensor. It uses sound waves to measure distance or detect the presence of objects. It emits high-frequency sound waves and measures the time it takes for the waves to bounce back after hitting an object. The sensor can determine the distance to the objects by calculating the time delay.

In the PipeDetective robot, the ultrasonic sensor is used for the robot’s auto motion in the pipes.

Figure 11: Ultrasonic Sensor

8. Servo Motor

A servo motor is a rotary actuator that enables precise control of angular position, velocity, and acceleration.

By receiving input signals, the servo motor adjusts its position to maintain the desired output, making it a key component in achieving precise motion control in various fields.

It is used to control the motion of the ultrasonic sensor for the robot's auto motion.

Figure 12: Servo motor

9. AC/DC Adapter

It is a device that converts alternating current (AC) electrical energy from a power outlet into direct current (DC) power suitable for powering electronic devices.

In PipeDetective, it is used to give 12V to the L298N motor driver, then connect the Arduino and other hardware components with the VSS pin (5V).

Figure 13: AC/DC Adapter

10. PCT-218

PCT-218, also known as Polymeric Conductive Tape, is a practical tool for unifying both the Ground (GND) and VCC (power) connections in electrical and electronic systems.
Using PCT-218 to unify the GND connections helps reduce ground loop issues and ensures consistent electrical potential throughout the system. Similarly, it aids in unifying VCC connections, enabling efficient power distribution and minimizing voltage drops.

Figure 15: PCT-218

4.4 Software

The web page streams a live video from the esp32 camera and some buttons and switches for the movement of the PipeDetective robot.

PipeDetective robot moves in three modes, manual, auto, and play path. It moves through the pipe to detect cracks using image processing with the canny edge detection algorithm.

The first mode is manual: PipeDetective robot moves forward, backward, right, and left manually and remotely using buttons on the web page.

The second mode is auto: PipeDetective robot moves in the pipe autonomously using the ultrasonic sensor to measure the distance, the ultrasonic sensor is connected with the servo motor to move right and left, in order to choose the suitable direction.

The third mode is play-path: PipeDetective robot moves the saved path. But to save the path, the user has to click on the save path button on the web page.

The speed of the PipeDetective robot can be controlled using two buttons, one to increase the speed and the other to decrease it.

Fifth Chapter

5. Results and Discussion

PipeDetective robot is a robot that moves through pipes and detects cracks using image processing. Meanwhile, the worker can observe the movement of PipeDetective from the application as a live stream. The worker can also choose the movement mode of the pipe (manual, auto, and play path).

Sixth Chapter

6. Conclusion and Recommendations

6.1 Conclusion

In conclusion, PipeDetective aimed to address the challenges faced by workers dealing with pipes and narrow spaces by developing a crack detection system using robotic platforms. Throughout the project, various aspects such as hardware selection, image processing algorithms, and video streaming were carefully considered and implemented. Despite the constraints encountered, including time limitations, design difficulties, and the sensitivity of electrical components, the project made significant progress.

6.2 Recommendations

Based on the findings and constraints encountered during the project, it is recommended to continue the development of the crack detection system using robots for pipes. To ensure the success of the project, close collaboration with industry experts and field professionals should be pursued to gain insights into the specific challenges and requirements of pipe inspection and maintenance. Additionally, continuous refinement of the hardware components, image processing algorithms, and navigation capabilities should be pursued to optimize the system's functionality.

Seventh Chapter

7. Future work

Future work will develop advanced remote-controlled repair techniques and tools using virtual reality (VR) technology to repair cracks. Additionally, the project can explore the implementation of movement capabilities in both vertical and horizontal directions, enabling the robot to navigate and inspect pipes more effectively and thoroughly.

Future work will also focus on adjusting the design to make it suitable for pipes of various sizes. One potential approach is to integrate a spring mechanism that allows the robotic system to adapt to various pipe diameters.

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