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Tile Grout Filling Robot

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Disclaimer

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Abstract

This project focuses on the development of a "Tile Grout Filling Robot," designed to automate the process of filling tile gaps with grout. The robot, constructed from a small wooden box with two front wheels and rounded metal supports at the back, includes a grout container and a mechanism for precise grout application. It autonomously follows tile gaps using a combination of sensors, including IR, laser, and camera modules, to ensure accurate grout placement. The robot is controlled by a Raspberry Pi 4 connected to an Arduino Uno, with movement powered by stepper motors. Testing was conducted on 40cm x 40cm tiles with 1-2 cm gaps, achieving satisfactory grout filling results. This innovation promises to reduce worker strain, time, and injury risks associated with manual grout application.

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Chapter 1

Introduction

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1.1 Background

Tile workers often face significant physical strain and time consumption when filling tile gaps manually, especially in large spaces. This task can lead to injuries in the legs, knees, and back due to prolonged kneeling and repetitive motion. Our project addresses these issues by automating the grout-filling process with a specialized robot.

1.2 Objectives

The primary objective of our project is to design and implement a robot capable of detecting tile gaps and filling them with grout efficiently, thereby reducing the physical effort, time, and injury risk for workers.

1.3 Significance

This project is groundbreaking as no similar robots currently exist on the market. Its potential impact includes significant time savings, reduced physical strain on workers, and a likely high market demand due to its innovative nature.

1.4 Organization of the report

This report is organized into six chapters: Introduction, Theoretical Background and Previous Work, Methodology, Results and Analysis, Discussion, and Conclusions and Recommendations. Each chapter systematically covers the development and findings of the project.

Chapter 2

Theoretical Background and Previous Work

Contents

2.1 Literature Review

Despite extensive research, no existing robots were found that are specifically designed for filling tile gaps with grout. The closest technology identified was a robot capable of placing tiles and applying cement, which is somewhat related but lacks grout-filling functionality.

2.2 Theoretical Framework

In designing our robot, we focused on maintaining a small form factor and ensuring efficient operation. The robot's grout container is sized to fill gaps in a 20m^2 room, balancing capacity with mobility.

2.3 Previous Work

There is no existing technology exactly like our grout-filling robot, making this project a novel contribution to the field of construction automation.

Chapter 3

Methodology

Contents

3.1 Standards and Specifications

Our project adheres to ISO 9241-210 (human-centered design processes for interactive systems) and IEEE 802.11 standards (wireless communication), ensuring usability and reliability.

3.2 Constraints

Several constraints influenced our design, including budget limitations, the variety of tile surfaces and shapes, and time constraints. Our image processing algorithm is currently optimized for tiles with solid colors without complex patterns or internal gaps.

3.3 Materials and Methods

3.3.1 Chassis

The robot's chassis is a cube with a black face, a camera in front, a mechanism for lowering the robot, 2 big wheels in front and 4 small wheels below, and the other sensors and components inside it.

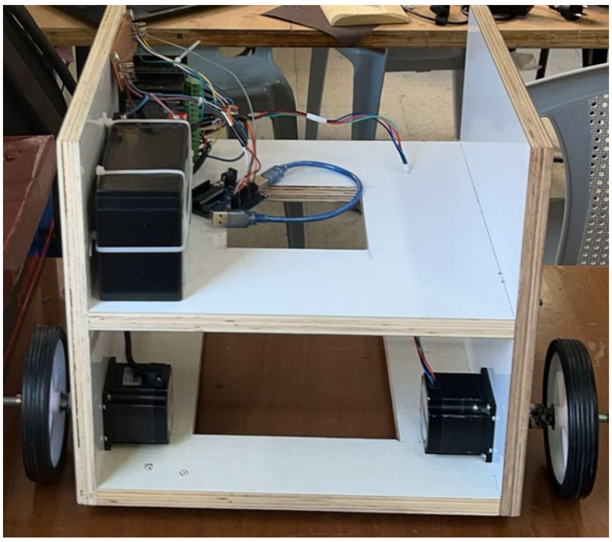

Figure 3.1: Chassis

3.3.2 Container for pressing and pushing the grout

It looks like a syringe, a container in which the grout is placed, and a smaller piece that goes inside the container and is connected to a stepper motor using a toothed rod. The motor rotates, the grout is pressed down, and it works with the servo motor to accurately regulate the grout's descent process.

Figure 3.2: Container for pressing and pushing the grout

3.3.3 Grout Float

It is used to compress and wipe the grout carefully.

Figure 3.3: Grout Float

3.3.4 Raspberry Pi 4

It's used as the main microcontroller[6].

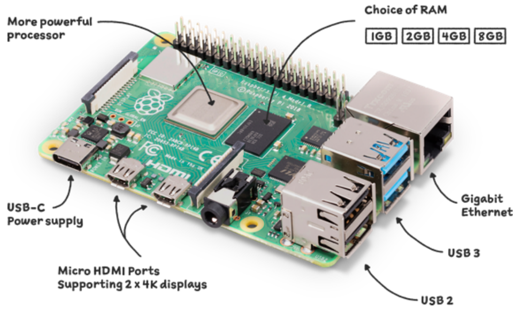

Figure 3.4: Raspberry Pi 4

3.3.5 Arduino Uno R3

It's used as the secondary microcontroller[2].

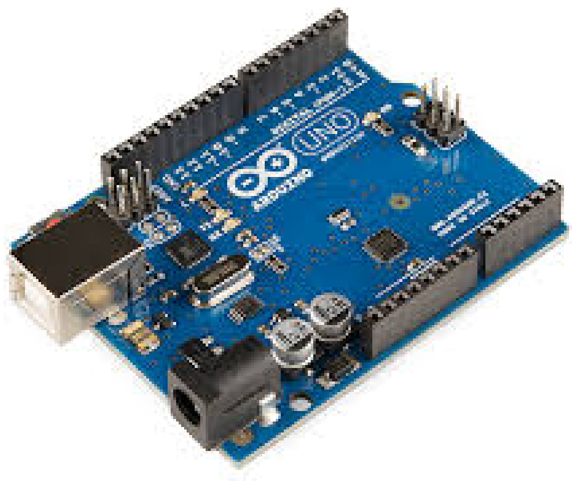

Figure 3.5: Arduino Uno R3

3.3.6 Raspberry Pi Camera Module 3 NoIR

It is used in image processing code to see lines between tiles and determine the direction of the robot's movement[9].

Figure 3.6: Raspberry Pi Camera Module 3 NoIR

3.3.7 IR Sensor Module

There are two of them to improve the robot's movement[10].

Figure 3.7: IR Sensor Module

3.3.8 Nema 23 Stepper Motor

There are 3 of them and it is used to move the robot and the pressure mechanism grout[7].

Figure 3.8: Nema 23 Stepper Motor

3.3.9 Microstep Driver

There are 3 of them and it's used to control the stepper[8].

Figure 3.9: Microstep Driver

3.3.10 Battery 12V 7-9A

It is used as a main power source with a voltage of 12V and a current of 7-9A[4].

Figure 3.10: Battery 12V 7-9A

3.3.11 Battery 5V 5A

There are 2 of them and it is used as a secondary power source with a voltage of 5V and a current of 5A[4].

Figure 3.11: Battery 5V 5A

3.3.12 2 position ON - OFF switch

It is used to separate the main battery from the project components.

Figure 3.12: 2 position ON - OFF switch

3.3.13 Connector Battery Charger

It is used to charge the battery from an external charger[5].

Figure 3.13: Connector Battery Charger

3.3.14 Battery Indicator

It's used to display the main battery charge percentage[1].

Figure 3.14: Battery Indicator

3.3.15 Ultrasonic Sensor

There are 2 of them and it is used to calculate the distance and determine the stopping point of the robot and the motors[12].

Figure 3.15: Ultrasonic Sensor

3.3.16 Jumper Wire

It is used to connect different robot components[11].

Figure 3.16: Jumper Wire

3.3.17 Connecter

It is used to connect different robot components.

Figure 3.17: Connecter

3.3.18 Servo Motor

It is used with the grout pressure method to control the descent of the grout and increase accuracy[3].

Figure 3.18: Servo Motor

3.3.19 Coupler

There are 3 of them and it is used to connect the stepper motor and the wheels.

Figure 3.19: Coupler

3.4 Safety Considerations

We adhered to safety protocols when handling materials and during the assembly of the robot, particularly when cutting wood, working with electrical wiring, and operating the battery and power systems.

Chapter 4

Results and Analysis

Contents

4.1 Data Collected

We conducted research and reviewed datasheets to ensure proper connectivity and functionality of the electronic components used in our robot.

4.2 Statistical Treatment

Although we did not conduct extensive statistical analysis, we used basic statistics to calculate distances for ultrasonic detection and angles for stepper motor control, as well as for image processing algorithms.

4.3 Error Estimation

Minor errors were observed in the ultrasonic sensor readings and image processing due to varying illumination conditions and the complexity of tile edges.

Chapter 5

Discussion

Contents

5.1 Interpretation of Results

Our robot successfully fills tile gaps with grout, providing a strong and aesthetically pleasing finish. This outcome demonstrates the robot's effectiveness in automating a traditionally manual and labor-intensive task.

5.2 Comparison with Existing Solutions

No existing projects or technologies match the functionality of our robot, making this an innovative solution in the field of construction automation.

5.3 Limitations

Challenges in image processing due to illumination variability and tile diversity were significant. Additionally, testing was limited to a small number of tiles, and the grout container's size was constrained by weight and robot mobility considerations.

Chapter 6

Conclusions and Recommendations

6.1 Summary of Results

We developed a unique robot capable of automating the grout-filling process, which has the potential to significantly reduce worker strain, save time, and minimize injury risks.

6.2 Recommendations

Future improvements could include a metal stand to extend the grout filling to the edges of the room, a larger grout container, enhanced robot speed, and improved image processing algorithms to handle a wider variety of tile shapes, patterns, and gaps.

6.3 Final Conclusion

Our project successfully demonstrates the feasibility of automating the grout-filling process with a specialized robot. The results indicate strong potential for practical application in the construction industry.

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