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Sustainable Cleaning Solutions: A Microcontroller-Driven Autonomous Floor Cleaning System

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Abstract - The autonomous cleaning bot is a state-of-the-art robotic system that utilizes advanced cutting-edge technology to automate the cleaning process. This paper aims at presenting the design and implementation of an autonomous cleaning robot that efficiently and effectively cleans a variety of indoor spaces, from homes to commercial buildings, using a combination of sensors, algorithms, and cleaning tools. Additionally, this can detect walls and obstacles. Using various sensors, a path planning algorithm is developed to enable the robot to efficiently move and clean floors. Also, this robot can be controlled in a wireless manner via any Bluetooth-enabled device like smartphone or tablet. Localization algorithms, stereoscopic vision, wireless networks, and human-machine interaction are integrated to promote the working performance of this cleaning robot. The system's ability to navigate to specific locations according to the user's ease and desire, in accordance with a map provided as predefined data, is showcased along with its capability to grasp objects and place them in designated locations, highlighting its improved perception and manipulation abilities. The robot is required to perform various functions such as cleaning the floor, picking up objects, and arranging them on the floor. For such a given floor task, the manipulability of the designated robot arms is analyzed through kinematics.

Keywords: Autonomous floor cleaner, Sensors, Motors, Bluetooth-enabled.

1. INTRODUCTION

In recent years, cleanliness has become essential to ensuring social and mental health. Traditional methods of dusting and sweeping are time-consuming and must be repeated daily to maintain hygienic standards. To solve this problem, robotic automatic floor cleaners have proven to be valuable tools that offer efficient and consistent cleaning by eliminating human error. These machines use advanced technologies such as ultrasonic sensors for obstacle avoidance and image processing for navigation, making them highly effective at keeping the floor clean without the need for human intervention. In addition, the incorporation of Bluetooth wireless capabilities and motor controllers increase mobility and control, making these devices more user-friendly and adaptable to different cleaning environments [4].

Robots capable of climbing vertical surfaces have been developed for specific applications. While these robots offer significant advantages in military, rescue, and construction applications, they face challenges such as high power consumption and complex control mechanisms. In contrast, we focus on floor cleaning robots that prioritize simplicity, efficiency and ease of use, making them ideal for everyday home use. These robots operate exclusively on horizontal surfaces, providing thorough cleaning with minimal energy consumption and complexity, providing a reliable and cost-effective solution for maintaining a clean environment [1] [2] [3] [4].

2. LITERATURE SURVEY

The literature on automated floor cleaning robots examines innovative approaches and advanced technologies to enhance efficiency, ease of use, and effectiveness. Key developments include the integration of AI and infrared camera sensors with Arduino Uno for automated temperature detection, significantly reducing human intervention. This technology, using the MLX90614 sensor, ensures precise measurements and is further advanced with real-time oxygen level monitoring, wirelessly transmitted via IoT. Studies also emphasize Bluetooth control, combining Arduino Uno with Bluetooth modules for wireless control via smartphones, enabling remote operation, scheduling, and real-time monitoring. Prototypes like CLEAR and TIDDY utilize components such as ultrasonic sensors, Raspberry Pi3, and servomotors for precise navigation and cleaning, demonstrating significant advancements in autonomous cleaning robots. Cost-effective and low-maintenance designs are highlighted, integrating wet and dry cleaning modes, AI-driven navigation, voice recognition, and advanced obstacle avoidance, making these technologies accessible to a broader audience.

Advancements in battery technology and power management have improved the efficiency and reliability of these robots, allowing for extended operation without frequent recharging. Autonomous robots now incorporate UV sterilization, vacuum cleaning, and disinfection techniques to enhance hygiene and safety. Multi-functional robots equipped with sensors and cameras can map environments, detect hazards, and assist in security surveillance, adapting to different cleaning scenarios using advanced AI algorithms and machine learning for optimized performance. Researchers are also focusing on eco-friendly designs, using sustainable materials and renewable energy sources like solar power to minimize environmental impact. Overall, the literature highlights significant progress in creating effective, user-friendly cleaning solutions that address hygiene, safety, and sustainability, with future advancements expected to bring even more sophisticated and versatile cleaning robots into daily life.

3. RESEARCH METHODOLOGY

A. Components:-

2.1 Arduino UNO R3 ATmega328P Microcontroller -

Acting as a central control unit with an operating voltage of 5V, input voltage of 7-12V, inout voltage of 6-20V and having 14 digital I/O pins, it interfaces with all other components to set up serial communication, processes input from sensors, performs coding and control algorithms, and then sends commands to actuators to control cleaning operations.

Fig. 1: Arduino UNO R3 ATmega328P Microcontroller

2.2 Serial Bluetooth Transceiver-

It enables wireless communication between the robot and a portable Bluetooth device, such as a smartphone or tablet, and receives control commands from the device, such as start/stop cleaning, change direction, or change the cleaning mode (vacuum or mop), thereby enabling remote control of the robot.

Fig.2: Serial Bluetooth Transceiver

2.3 Ultrasonic sensor HC-SR04 -

Having a power supply of 5V, operating current of 15mA and operating frequency range of 40Hz, it continuously emits ultrasonic waves and measures the time it takes for the echo to return, which helps the robot detect obstacles and move around them, avoiding collisions.

Fig.3: Ultrasonic sensor HC-SR04

2.4 SG90 Micro Servo Motor -

It controls the movement of the ultrasonic sensor as required to provide a wider detection range for calculating distances from obstacles and help the robot avoid them.

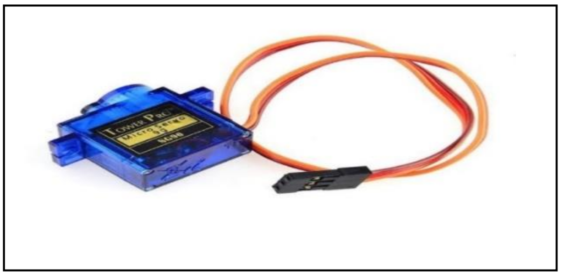

Fig. 4: SG90 Micro Servo Motor

2.5 L239D DC Motor Drive Shield -

It interfaces with the Arduino microcontroller and provides the necessary current and voltage to the DC motors based on the control signals from the Arduino, allowing for overall precise motion control.

Fig. 5: L239D DC Motor Drive Shield

2.6 6V DC motor -

With an operating voltage of 4.5V to 9V and an RPM of 17000-18000, it converts electrical energy obtained from batteries into mechanical energy to operate the robot's vacuum system. It has a shaft that rotates when connected to a battery.

Fig. 6: 6V DC Motor

B. Workflow:-

Explanation: The Arduino UNO microcontroller acts as the central control unit, coordinating the operation of various connected components. These components include: Ultrasonic Sensor, Gear Motors, Servo Motor, DC Motor, and DC Motor Drive Shield. The microcontroller integrates these components, ensuring they work together seamlessly to achieve the desired functionality. Additionally, the Arduino UNO is connected to a Bluetooth Serial Transceiver, which enables wireless communication. This setup allows for remote control and monitoring of the system, facilitating wireless locomotion and interaction with the microcontroller from a distance.

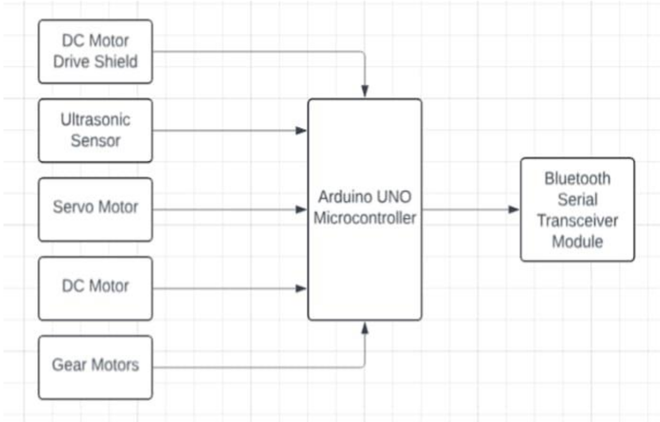

Fig. 7: Workflow Diagram

4. WORKING PRINCIPLE

According to the circuit diagram below, this autonomous cleaning robot operates with an Arduino UNO R3 ATmega328P ATmega16U2 as the central microcontroller, interfacing with an L239D DC Motor Drive Shield which, in turn, connects every other component together for explicit control of their movements and functions. An HC-SR04 Ultrasonic Sensor is connected to the motor drive shield and carries out the responsibility of detecting obstacles by continuously emitting ultrasonic waves and calculating the distance of the robot from the interference in front of it by the time taken for the echo to return allowing the bot to carefully maneuver around large objects. An SG90 Micro Servo Motor adjusts the angle of the ultrasonic sensor for a wider detection range and more efficient navigation, with the help of small gears present inside it. A Bluetooth Serial Transceiver module is added to the circuit for wireless, remote control from any Bluetooth-enabled device. Commands sent via Bluetooth by the device to the robot are processed by the Arduino, which adjusts the motors accordingly to perform vacuuming and mopping tasks autonomously. The DC motor drive shield controls four DC Dual Shaft BO Motors with wheels, enabling systematic movement of the robot in various directions like forward, backward and sideways. A 6V DC Motor powers the vacuum mechanism, while two 9V Lithium-ion Batteries provide the necessary power supply to all the elements.

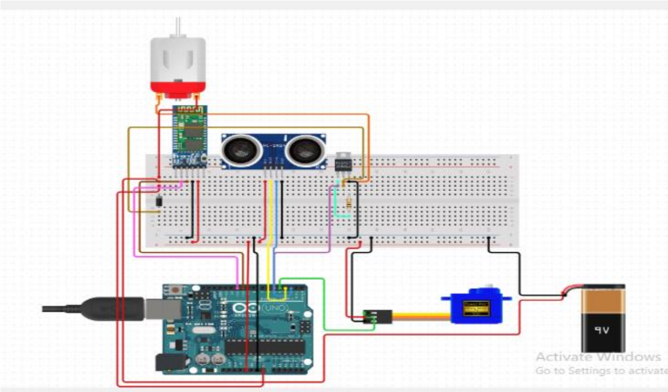

Fig. 8: Circuit Diagram-Smart Autonomous Floor Cleaning Robot

5. RESULT AND DISCUSSION

Sl. No.1	Duration	Area to be covered	Area covered	Accuracy
Sample 1	1 min	1 sq ft	0.93 sq ft	93%
Sample 2	2 mins	1 sq ft	0.91 sq ft	91%
Sample 3	3 mins	1 sq ft	1 sq ft	100%
Sample 4	4 mins	1 sq ft	0.93 sq ft	93%
Sample 5	5 mins	1 sq ft	0.99 sq ft	99%
Sample 6	6 mins	1 sq ft	0.94 sq ft	94%
Sample 7	7 mins	1 sq ft	0.92 sq ft	92%
Sample 8	8 mins	1 sq ft	0.9 sq ft	90%
Sample 9	9 mins	1 sq ft	0.91 sq ft	91%
Sample 10	10 mins	1 sq ft	0.98 sq ft	98%

Sl. No.2	Duration	Area to be covered	Area covered	Accuracy
Sample 1	1 min	2 sq ft	1.99 sq ft	99%
Sample 2	2 mins	2 sq ft	1.94 sq ft	94%
Sample 3	3 mins	2 sq ft	1.93 sq ft	93%
Sample 4	4 mins	2 sq ft	1.92 sq ft	92%
Sample 5	5 mins	2 sq ft	1.95 sq ft	95%
Sample 6	6 mins	2 sq ft	1.98 sq ft	98%
Sample 7	7 mins	2 sq ft	1.97 sq ft	97%
Sample 8	8 mins	2 sq ft	1.95 sq ft	95%
Sample 9	9 mins	2 sq ft	1.91 sq ft	91%
Sample 10	10 mins	2 sq ft	2 sq ft	100%

Sl. No.3	Duration	Area to be covered	Area covered	Accuracy
Sample 1	1 min	3 sq ft	2.91 sq ft	91%
Sample 2	2 mins	3 sq ft	2.93 sq ft	93%
Sample 3	3 mins	3 sq ft	2.95 sq ft	95%
Sample 4	4 mins	3 sq ft	2.91 sq ft	91%
Sample 5	5 mins	3 sq ft	3 sq ft	100%
Sample 6	6 mins	3 sq ft	2.97 sq ft	97%
Sample 7	7 mins	3 sq ft	2.96 sq ft	96%
Sample 8	8 mins	3 sq ft	2.92 sq ft	92%
Sample 9	9 mins	3 sq ft	2.94 sq ft	94%
Sample 10	10 mins	3 sq ft	2.96 sq ft	96%

Sl. No.4	Duration	Area to be covered	Area covered	Accuracy
Sample 1	1 min	4 sq ft	3.96 sq ft	96%
Sample 2	2 mins	4 sq ft	3.95 sq ft	95%
Sample 3	3 mins	4 sq ft	3.97 sq ft	97%
Sample 4	4 mins	4 sq ft	3.9 sq ft	90%
Sample 5	5 mins	4 sq ft	3.92 sq ft	92%
Sample 6	6 mins	4 sq ft	3.95 sq ft	95%
Sample 7	7 mins	4 sq ft	3.97 sq ft	97%
Sample 8	8 mins	4 sq ft	3.91 sq ft	91%
Sample 9	9 mins	4 sq ft	3.92 sq ft	92%
Sample 10	10 mins	4 sq ft	3.93 sq ft	93%

Sl. No.5	Duration	Area to be covered	Area covered	Accuracy
Sample 1	1 min	5 sq ft	4.91 sq ft	91%
Sample 2	2 mins	5 sq ft	4.95 sq ft	95%
Sample 3	3 mins	5 sq ft	5 sq ft	100%
Sample 4	4 mins	5 sq ft	4.92 sq ft	92%
Sample 5	5 mins	5 sq ft	4.94 sq ft	94%
Sample 6	6 mins	5 sq ft	4.97 sq ft	97%
Sample 7	7 mins	5 sq ft	4.98 sq ft	98%
Sample 8	8 mins	5 sq ft	4.92 sq ft	92%
Sample 9	9 mins	5 sq ft	4.94 sq ft	94%

Sample 10	10 mins	5 sq ft	4.96 sq ft	96%

Table 1: Experimental data analysis

6. CONCLUSIONS AND FUTURE SCOPE

The successful articulation of all these components results in a versatile and efficient autonomous cleaning robot. By leveraging Bluetooth control, users can remotely operate the robot from any Bluetooth-enabled device, thereby, enhancing convenience. The systematic methodology ensures that each component serves its intended purpose, contributing to the overall functionality and reliability of the robot. This methodology provides a comprehensive approach to developing a Bluetooth-controlled Arduino-based cleaning robot, ensuring clarity and coherence in the design and implementation process.

With the help of improved sensors, the robot will be able to learn from its surrounding environment more efficiently, it will have enhanced compatibility with voice assistants like Amazon Alexa, Google Assistant, and Apple Siri and also feature multi-surface adaptation in order to automatically adjust its cleaning method based on the type of flooring.

Fig. 9: Prototype of autonomous floor cleaning device

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