e-ISSN:2582-7219

INTERNATIONAL JOURNAL OF MULTIDISCIPLINARY RESEARCH

IN SCIENCE, ENGINEERING AND TECHNOLOGY

Volume 7, Issue 1, April 2024

INTERNATIONAL STANDARD SERIAL NUMBER INDIA

Impact Factor: 7.521

International Journal Of Multidisciplinary Research In Science, Engineering and Technology (IJMRSET)

| ISSN: 2582-7219 | www.ijmrset.com | Impact Factor: 7.521| | Monthly Peer Reviewed & Refereed Journal |

|| Volume 7, Issue 1, April 2024 ||

International Conference on Recent Development in Engineering and Technology – ICRDET 24

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Dhaanish Ahmed Institute of Technology, KG Chavadi, Coimbatore, Tamilnadu, India

Epic- Cleaner: Autonomus Dust-Cleaning Robot Using Arduino

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ABSTRACT: This study presents the design and development of an autonomous dust-cleaning robot utilizing Arduino microcontroller technology. The robot is engineered to navigate indoor environments efficiently while employing sensors to detect and target areas requiring cleaning. By integrating Arduino-based control systems with robust mechanical components, the robot autonomously maneuvers through diverse surfaces, effectively collecting dust and debris. The project encompasses aspects of robotics, embedded systems, and artificial intelligence, offering a practical solution for household and commercial cleaning tasks. Through experimentation and validation, the efficacy and reliability of the autonomous dust-cleaning robot are demonstrated, showcasing its potential to enhance cleanliness and efficiency in various indoor settings.

KEYWORDS: Autonomous Robot, Dust Cleaning, Arduino Microcontroller, Embedded Systems, Robotics, Sensor Fusion, Indoor Cleaning, Smart Home Technology.

I. INTRODUCTION

An autonomous dust-cleaning robot stands as an innovative solution to combat the persistent issue of dust accumulation in indoor environments. By harnessing the power of robotics and smart technology, this state-of-the-art device is meticulously engineered to autonomously traverse indoor spaces, swiftly detect and eliminate dust particles, and uphold pristine air quality standards. At its core lies a robust and agile robotic platform, featuring either wheels or tracks for seamless mobility across diverse indoor surfaces. Designed with versatility in mind, this platform effortlessly maneuvers across hardwood floors, carpets, tiles, and rugs, ensuring comprehensive coverage during cleaning operations. To perceive its surroundings with precision, the robot is equipped with a sophisticated array of sensors, including cameras, metal detector sensors, ultrasonic sensors, and infrared sensors. These sensors collectively empower the robot to accurately assess its environment, detect potential obstacles, generate detailed maps of the area, and pinpoint areas with significant dust accumulation. Additionally, integrated dust sensors or particulate matter sensors play a pivotal role in monitoring air quality by detecting dust particles suspended in the air or settled on surfaces. This real-time feedback enables the robot to intelligently prioritize cleaning tasks, focusing on areas with heightened dust concentrations for maximum efficacy. The cleaning prowess of the robot is further augmented by a diverse range of cleaning mechanisms tailored to different surfaces and dust types. These mechanisms may encompass rotating brushes, powerful suction mechanisms, microfiber cloths, or electrostatic dusters, meticulously engineered to capture dust particles from floors, carpets, furniture, and other surfaces with unparalleled efficiency. Moreover, the robot operates autonomously, alleviating the need for human intervention by autonomously scheduling cleaning sessions based on occupancy patterns or real-time air quality metrics.

II. RELATED WORK

In [1] Cleaning robots have been gaining traction amongst various industries globally, with domestic floor cleaning robots being the most widespread. These robots usually employ brushes with a vacuum unit for dry cleaning purposes. For a self-reconfigurable tiling-based floor cleaning robot, hTetro, a modular sweeping module was developed. In [2] the autonomous robotic vacuum cleaner is an automatic and programmed device to clean the surface with the help of a

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mop and vacuum cleaner. This is the robot that automatically cleans the dirty surface by using a set of commands given by the user through the smartphone. In [3] Robots have become an integral part of 21st century due to their excessive use in household, hotels, offices etc. Cleaning which is of paramount importance for healthy living is being neglected due to lack of time arising from busy lifestyle. Taking this in consideration we are proposing an automatic cleaner robot that can perform all the cleaning activities without any human guidance. In [4] it investigates the product's social impact with respect to the attitude of customers towards a systematic floor cleaner and how much a robot influences a lifestyle. Systematic cleaning was an important feature and modifications to the environment to support the navigation of the robot. The robot employs a systematic cleaning strategy that maps the environment using GPS like indoor localization. In [5] the main goal of this research paper is to create a robot that reduces a person's effort in scrubbing and sweeping while also finding a way to resolve the drawbacks of the previous cleaning method. Robots are using for different purposes in home automation. In [6] create solar-powered mobile floor cleaning equipment that may be used as an alternative to traditional floor cleaning machines. Because of the high cost of manpower, time, effort, and affordability, automated floor cleaning devices have been widely employed in developing countries for many years. This abstract is based on our creative concept to design, develop, and manufacture a semi-automatic solar-powered mobile floor cleaning machine that will run on solar energy, mobile communication, battery power, or electricity.

III. PROPOSED METHOD

The implementation of an autonomous dust-cleaning robot offers multifaceted benefits, ranging from time and labor savings to enhanced hygiene and safety in indoor environments. By automating the cleaning process, this innovative technology significantly reduces the time and manpower required to tackle large or hard-to-reach areas, leading to increased efficiency and cost-effectiveness in cleaning operations. Moreover, the meticulous removal of dust and allergens by the robot not only enhances the overall hygiene of indoor spaces but also mitigates potential health risks associated with airborne pollutants, thereby promoting a safer and more comfortable environment for occupants. Furthermore, the adaptability of the robot to different floor types and conditions ensures optimized cleaning performance across diverse surfaces, further enhancing its efficacy in maintaining cleanliness. Additionally, by providing real-time data and insights on the cleaning process and the state of the floors, the robot enables informed decision-making and proactive maintenance strategies, ultimately contributing to the long-term maintenance and preservation of indoor environments. Overall, the integration of an autonomous dust-cleaning robot represents a transformative solution for achieving cleaner, safer, and more efficient indoor spaces.

- Time-saving by automating cleaning tasks.
- Reduction in labor costs associated with manual cleaning.
- Improved hygiene by thorough and consistent cleaning.
- Enhanced air quality through dust and allergen removal.
- Versatility in adapting to various floor types and surfaces.
- Convenience with scheduling and remote control features.
- Accessibility for individuals with mobility limitations.
- Potential for increased productivity in other tasks.
- Eco-friendly operation with energy-efficient designs.

IV. IMPLEMENTATION

Assembly: Begin by assembling the chassis and mounting the motors, wheels, sensors, and vacuum mechanism securely.

Arduino Setup: Install the Arduino IDE on your computer. Connect the Arduino board to your computer via USB.

Sensor Interfacing: Write code to interface with the ultrasonic sensors for obstacle detection and dust sensors for dust detection. Calibrate the sensors as necessary.

Motor Control: Implement motor control algorithms to drive the robot, including forward, backward, left, and right movements.

Obstacle Avoidance: Develop logic to enable the robot to detect obstacles using ultrasonic sensors and navigate around them autonomously.

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Dust Detection and Collection: Integrate dust sensors to detect areas with high dust accumulation. Activate the vacuum mechanism to collect dust when detected.

Testing and Refinement: Test the robot in various environments to ensure proper functionality. Refine the code and hardware as needed for optimal performance.

Optional Features: Implement additional features such as Wi-Fi connectivity for remote control, scheduling, or mapping capabilities.

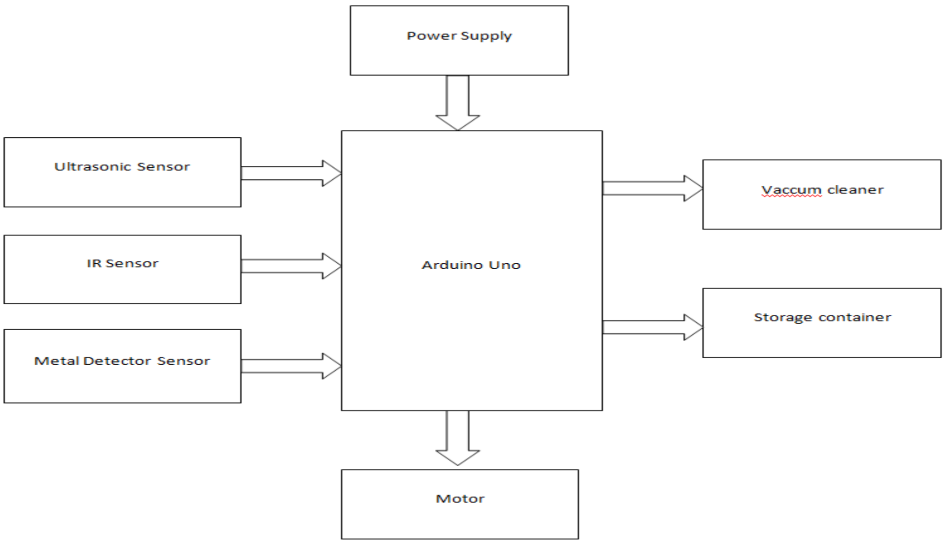

Figure 1: Block diagram of working model

Hardware components

- Motor driver
- DC motors for propulsion
- Wheels for movement
- Ultrasonic sensors
- Dust sensors for dust detection
- Vacuum motor and suction mechanism
- Chassis and frame for the robot
- Power source
- IR sensor

Arduino UNO

Microcontroller

A micro-controller is a small computer on a single integrated circuit containing a processor core, memory, and programmable input/ output peripherals The important part for us is that amicro-controller contains the processor (which all computers have) and memory, and some input/output pins that you can control. (often called GPIO - General Purpose Input Output Pins).

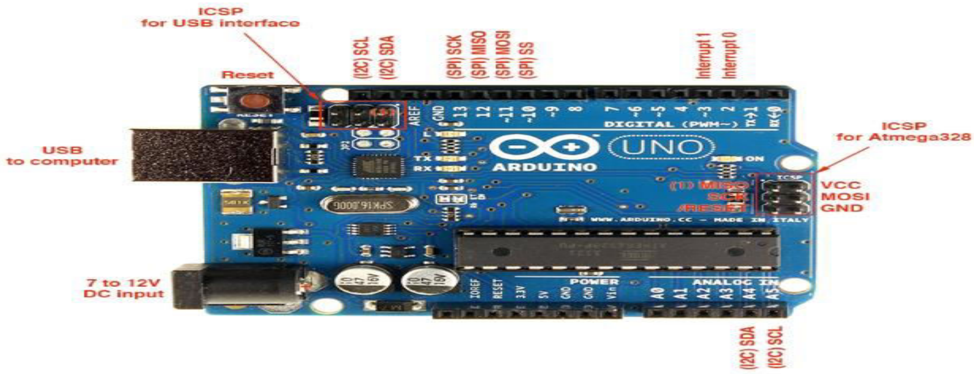

Figure2: Arduino board

IR Sensor

Infrared (IR) sensors are electronic devices designed to detect infrared radiation emitted by objects. These sensors operate on the principle that all objects with a temperature above absolute zero emit heat energy in the form of infrared radiation.

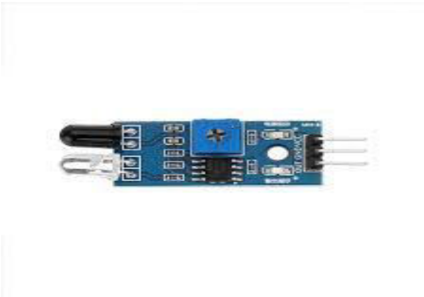

Figure3: IR Sensor

Ultrasonic sensor

Ultrasonic sensors are devices that use sound waves with frequencies higher than the human audible range to detect objects and measure distances. The working principle of ultrasonic sensors is based on the emission and reception of ultrasonic waves, which propagate through the air and reflect off objects in their path. The distance to the object can be calculated using the formula:

Distance = (Time × Speed of Sound) / 2

Figure4.4: Ultrasonic sensor

Motor driver

The L293D Motor Driver Module is a popular integrated circuit (IC) commonly used to control the direction and speed of DC motors. It consists of two H-bridge circuits, each capable of driving a single motor in both forward and reverse directions.

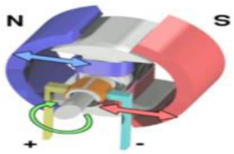

Figure4.9: DC Motor

$$I = V / R$$

where I – current, measured in amperes (A);
V – applied voltage, measured in volts (V);
R – resistance, measured in ohms (Ω).

The consumed electrical power of the motor is defined by the following formula:

$$P_{in} = I * V$$

where Pin – input power, measured in watts (W);
I – current, measured in amperes (A);
V – applied voltage, measured in volts (V).

Motors supposed to do some work and two important values define how powerful the motor is. It is motor speed and torque – the turning force of the motor. Output mechanical power of the motor could be calculated by using the following formula:

$$P_{out} = \tau * \omega$$

where Pout – output power, measured in watts (W);
τ – torque, measured in Newton meters (N•m);
ω – angular speed, measured in radians per second (rad/s).

It is easy to calculate angular speed if you know rotational speed of the motor in rpm:

$$\omega = rpm * 2\pi / 60$$

where ω – angular speed, measured in radians per second (rad/s);
rpm – rotational speed in revolutions per minute;
π – mathematical constant pi (3.14).
60 – number of seconds in a minute.

If the motor has 100% efficiency all electrical power is converted to mechanical energy. However such motors do not exist. Even precision made small industrial motors such as one we use as a generator in generator kit have maximum efficiency of 50-60%. Motors built from our kits usually have maximum efficiency of about 15% (see *Experiments* section on how we estimated this).Don't be disappointed with 15% maximum efficiency.

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$$E = Pout / Pin$$

therefore

$$Pout = Pin * E$$

after substitution we get

$$\tau * \omega = I * V * E$$

$$\tau * rpm * 2\pi / 60 = I * V * E$$

and the formula for calculating torque will be

$$\tau = (I * V * E * 60) / (rpm * 2\pi)$$

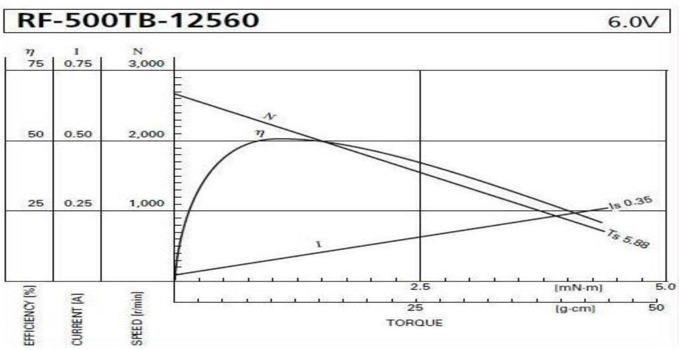
Our estimated 15% efficiency represents maximum efficiency of the motor which occurs only at a certain speed. Efficiency may be anywhere between zero and the maximum; in our example below 1000 rpm may not be the optimal speed so the for the sake of calculations you may use 10% efficiency (E = 0.1).

Example: speed is 1000 rpm, voltage is 6 Volts, and current is 220 mA (0.22 A):

$$\tau = (0.22 * 6 * 0.1 * 60) / (1000 * 2 * 3.14) = 0.00126 \text{ N•m}$$

As the result is small usually it is expressed in milliNewton meters (mN•m). There is 1000 mN•m in 1 N•m, so the calculated torque is 1.26 mN•m. It could be also converted further to still common gram force centimeters (g-cm) by multiplying the result by 10.2, i.e. the torque is 12.86 g-cm.

In our example input electrical power of the motor is 0.22 A x 6 V = 1.32 W, output mechanical power is 1000 rpm x 2 x 3.14 x 0.00126 N•m /60 = 0.132 W.



Software Requirement

- Arduino IDE
- Embedded C

ARDUINO IDE:

- Arduino IDE is an open source software that is mainly used for writing and compiling the code into the Arduino Module.
- It is an official Arduino software, making code compilation too easy that even a common person with no prior technical knowledge can get their feet wet with the learning process.

The IDE environment is mainly distributed into three sections

- **1. Menu Bar**
- **2. Text Editor**
- **3. Output Pane**

Figure4.10: Home page of arduino IDE

Embedded C

Now that we have seen a little bit about Embedded Systems and Programming Languages, we will dive in to the basics of Embedded C Program. We will start with two of the basic features of the Embedded C Program: Keywords and Data types.

Keywords in Embedded C

A Keyword is a special word with a special meaning to the compiler (a C Compiler for example, is a software that is used to convert program written in C to Machine Code). For example, if we take the Kiel's Cx51 Compiler (a popular C Compiler for 8051 based Microcontrollers) the following are some of the keywords:

- bit
- sbit
- sfr
- small
- large

V. SIMULATION RESULTS

The EPIC-CLEANER project has yielded promising results in the development and implementation of the hTrihex autonomous dust-cleaning robot platform. The platform demonstrates remarkable efficiency in navigating through diverse environments, identifying obstacles, and autonomously adapting its cleaning strategy to ensure thorough coverage. The integration of advanced sensors, coupled with state-of-the-art motion control algorithms, has facilitated precise and effective cleaning performance across various floor surfaces. The robust mechanical design of hTrihex lays a strong foundation for its performance, enabling it to traverse different floor types and access hard-to-reach areas with ease. Moreover, the incorporation of advanced electronic components enhances its sensing capabilities, allowing for intelligent decision-making based on real-time environmental feedback. The derived kinematics equations and the proposed robust backstepping design for motion control have proven to be instrumental in ensuring smooth and precise movement of hTrihex. These advancements contribute to the overall efficiency and effectiveness of the cleaning process, ultimately leading to cleaner and healthier living environments for users. Moving forward, continued research and development efforts will be focused on further refining hTrihex's capabilities, including optimizing the design of the cleaning module, addressing challenges such as wheel slip and drag on different floor surfaces, and exploring advanced control strategies to adapt to varying environmental conditions. In conclusion, the EPIC-CLEANER project showcases the transformative potential of autonomous dust-cleaning robots in revolutionizing clean living, offering a glimpse into the future where automation and intelligence converge to create healthier and more comfortable living spaces.

VI. CONCLUSION AND FUTURE WORK

One of the cornerstone achievements of the project lies in the meticulous mechanical design of hTrihex, meticulously engineered to optimize its cleaning efficacy. The robot's unique configuration enables it to navigate seamlessly across various floor surfaces, reaching even the most challenging areas with ease. Moreover, the project introduces a groundbreaking robust backstepping design for motion control, validated through rigorous numerical simulations and real-world experiments, showcasing its effectiveness in enhancing cleaning performance.

Future work for EPIC-CLEANER entails an array of advancements to bolster its effectiveness and versatility. One avenue is the refinement of its sensor suite, integrating cutting-edge technologies like lidar and hyperspectral imaging to enhance dust detection and navigation accuracy. Additionally, adaptive cleaning algorithms driven by machine learning could enable EPIC-CLEANER to dynamically adjust its cleaning strategies based on environmental factors and user preferences. Expanding its capabilities to clean various surfaces beyond floors, such as walls and furniture, presents another promising area for development. Integration with smart home systems could streamline communication and coordination, while prioritizing energy efficiency and sustainability through the use of low-power components and eco-friendly materials is paramount.

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