RESEARCH ON DEVELOPING AND BUILDING AN AUTONOMOUS ROBOT FOR SURFACE CLEANING

CRIȘU Dragoș-Constantin, BĂLAN Andrei-Teodor, COJOCARU Michael, LUPU Adrian-Cătălin, MARINESCU Marinela Nicoleta, BUȚU Larisa

Faculty: Faculty of Industrial Engineering and Robotics, Specialization: Robotics, Year of Study: I, e-mail: dragos.crisu@gmail.com

The study "Research on developing and building of an autonomous robot for cleaning surfaces" aims to develop an autonomous robot capable of industrial cleaning large surfaces after various processes, such as the machining process. The robot will be equipped with a sensor system and navigation algorithms that will allow it to avoid obstacles and move autonomously in the workspace. Additionally, it will be equipped with an efficient cleaning system that can be adapted to different types of surfaces. A prototype of the robot has been built on a limited budget, and the cleaning brushes will be interchangeable to meet different cleaning needs. Developing such an autonomous robot could bring multiple benefits to the metal processing industry, such as reducing cleaning time and cost, as well as improving working conditions for employees.

KEYWORDS: autonomous robot, sensor system and navigation algorithms, prototype of the robot, benefits to the metal processing industry

1. Introduction

Certainly, robotics is one of the most interesting and promising branches of modern engineering. In recent years, autonomous robots have started to penetrate various fields, from the automotive and aerospace industries to medicine and space exploration. In this context, research on the design and development of an autonomous surface cleaning robot is particularly important in the metal processing industry, where surface cleaning is a recurring and necessary task.

Our objective was to develop an autonomous robot capable of performing industrial cleaning on large surfaces after various processes, such as the machining process. For this purpose, we used a scaled-down prototype constructed with different materials and equipped it with Arduino as the microcontroller and front sensors. We programmed the Arduino to enable the robot to operate using its onboard sensors and perform surface cleaning efficiently and autonomously.

Fig. 1. Arduino Microcontroller

2. Current stage

The current stage of research regarding the design and development of an autonomous surface cleaning robot has led to the development of a prototype robot capable of performing industrial cleaning operations. This robot is constructed using various components such as Arduino, ultrasonic sensors, and an efficient cleaning system [3].

Over the past few years, research in the field of robotics has progressed rapidly, enabling the development of increasingly advanced robots. Regarding cleaning robots, the market is already saturated with models that are manually or semi-automatically controlled but lack the ability to autonomously navigate and perform cleaning operations on large surfaces.

The prototype of the autonomous surface cleaning robot developed within this research represents an innovative solution to this problem. By utilizing a system of sensors and navigation algorithms, this robot can avoid obstacles and autonomously navigate in the working space.

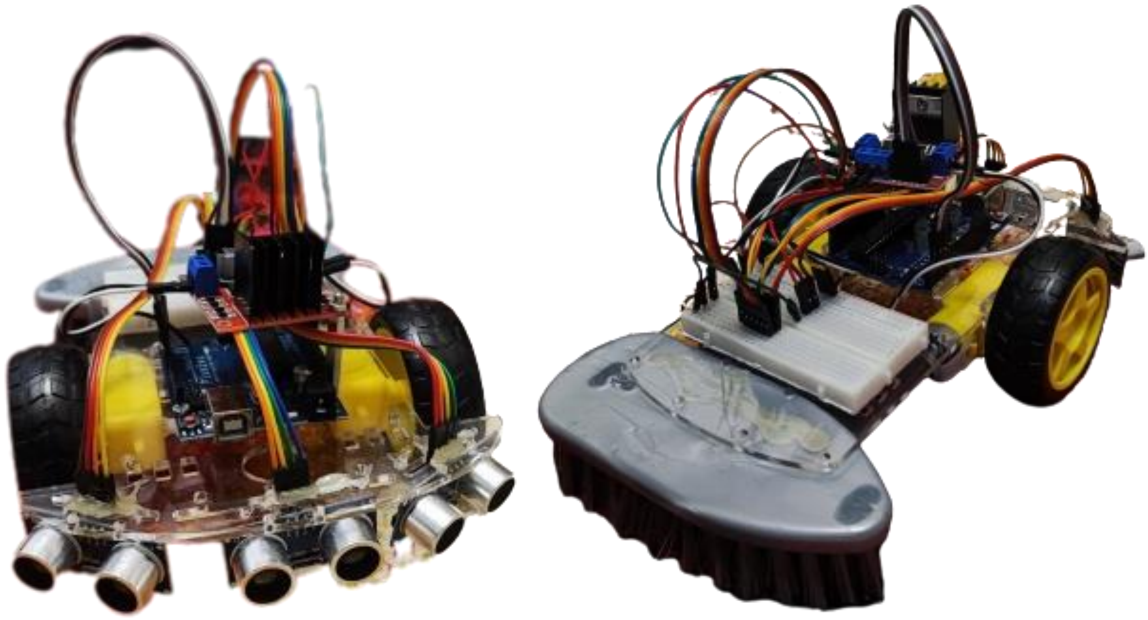

Fig. 2. Prototipul de robot autonom

In the robot's code, we have utilized a multitude of functions to achieve the current efficiency of the autonomous prototype robot. An important equation used in the prototype's code is equation (1), where d represents the distance at which the sensor is from the obstacle, expressed in centimeters, Δt is the time in which the sensor receives the reflected sound from the obstacle. We multiply it by 0.034 to convert the speed of sound to centimeters and divide by 2 for one-way duration since the sound needs to travel back to the sensor to provide information, similar to echolocation. Additionally, lines of code (2,3) are crucial to the functioning of the prototype as they implement a way to avoid obstacles. These lines of code check if the distance detected by the front sensor is smaller than the maximum allowed distance and if the distances detected by the side sensors are also smaller than the maximum allowed distance. If these conditions are met, the prototype is programmed to avoid the obstacles by rotating in the opposite direction of the obstacle and then moving forward. This approach enables the prototype to detect obstacles in a timely manner and efficiently avoid them, preventing potential collisions and damage to the robot.

As improvements, we intend to incorporate infrared sensors in the next version of the prototype as they offer higher performance and lower margin of error compared to the current ultrasonic sensors. We also plan to replace the brush at the back of the robot with a rotating brush to further enhance the cleaning process. Optimizing the code, replacing Arduino with a more powerful microcontroller or even a mini-computer are also part of our plans. Additionally, to accommodate these enhancements, we will install a more powerful motor to compensate for the added weight.

$$\mathrm{D} = \frac{\Delta t \cdot 0.034}{2} \quad (1)$$

$$\mathrm{distancef} < distance\_max \ \&\& \ distanced < distance\_\mathrm{max} \quad (2)$$

$$\mathrm{distancef} < distance\_max \ \&\& \ distances < distance\_\mathrm{max} \quad (3)$$

3. Robot Production Technology

The prototype of the autonomous surface cleaning robot was developed using a series of key components to ensure proper functionality and performance. Among the components used are an Arduino board, three HC-SR04 ultrasonic sensors, an L298N motor driver, and two motors. These components were carefully selected to meet the specific requirements of the robot and enable precise control of movement and obstacle detection in the working environment.

An important aspect of the prototype is its power system. It utilizes two 1850mAh batteries, which provide sufficient energy for the robot to operate for an extended period of time. The choice of suitable batteries was crucial to ensure the autonomy and mobility of the robot during the surface cleaning process.

Regarding the cleaning brush, it should be mentioned that the prototype was equipped with a standard brush, which is commonly available in the market. Due to cost constraints during the prototype development stage, we did not have the opportunity to order or design a specialized brush tailored to the specific needs of the robot. However, even with a standard brush, the prototype has demonstrated satisfactory capabilities in terms of surface cleaning.

4. Construction stages

I. Hardware Development

We initiated the construction process of the autonomous surface cleaning robot by starting with a robot chassis kit [2], which we purchased at a budget-friendly price from a specialized robot parts website. This kit included two electric motors and the mounting system for the chassis, providing us with a sturdy foundation for building the robot. Additionally, the kit included a small wheel, similar to a caster wheel, which served the purpose of supporting and balancing the robot. However, we decided to replace the wheel with a brush, considering its dual role in our prototype: both cleaning and supporting the robot.

The first step in constructing this robot was to mount the Arduino board to facilitate any potential replacements in case of short circuits or malfunctions. The Arduino board was securely attached to the chassis using two screws, ensuring stability and accessibility. The next step involved mounting a breadboard, a board that facilitates connections and allows for modifications within the prototype. To ensure power supply, we proceeded with mounting the power source. Due to space constraints, we opted to mount the power source on the lower part of the chassis, with a switch directly connected to it.

Another crucial step was the installation of the motor driver. Initially, we considered using an L298D motor driver shield, which would have allowed us to connect multiple motors for future enhancements. However, we encountered an issue with the shield blocking all digital pins. Our solution was to use a standard motor driver, L298N. This alternative allowed us to bypass the restrictions imposed by the previously mentioned shield. Regarding the installation of the motor driver, we faced the same challenge as with the power source, but we found a solution by mounting it above the Arduino board using a pillar to ensure stable fixation.

The last hardware components mounted on the chassis were the three HC-SR04 ultrasonic sensors, placed underneath the chassis for better visibility. One sensor was oriented directly in the direction of the robot's movement, while the other two were mounted laterally to cover a wider angle of visibility. After mounting all the components on the chassis, we proceeded to establish the connections between them (Fig. 3.). This process involved connecting the Arduino board to the motor driver, ultrasonic sensors, and power source, ensuring correct interaction and efficient operation of all components.

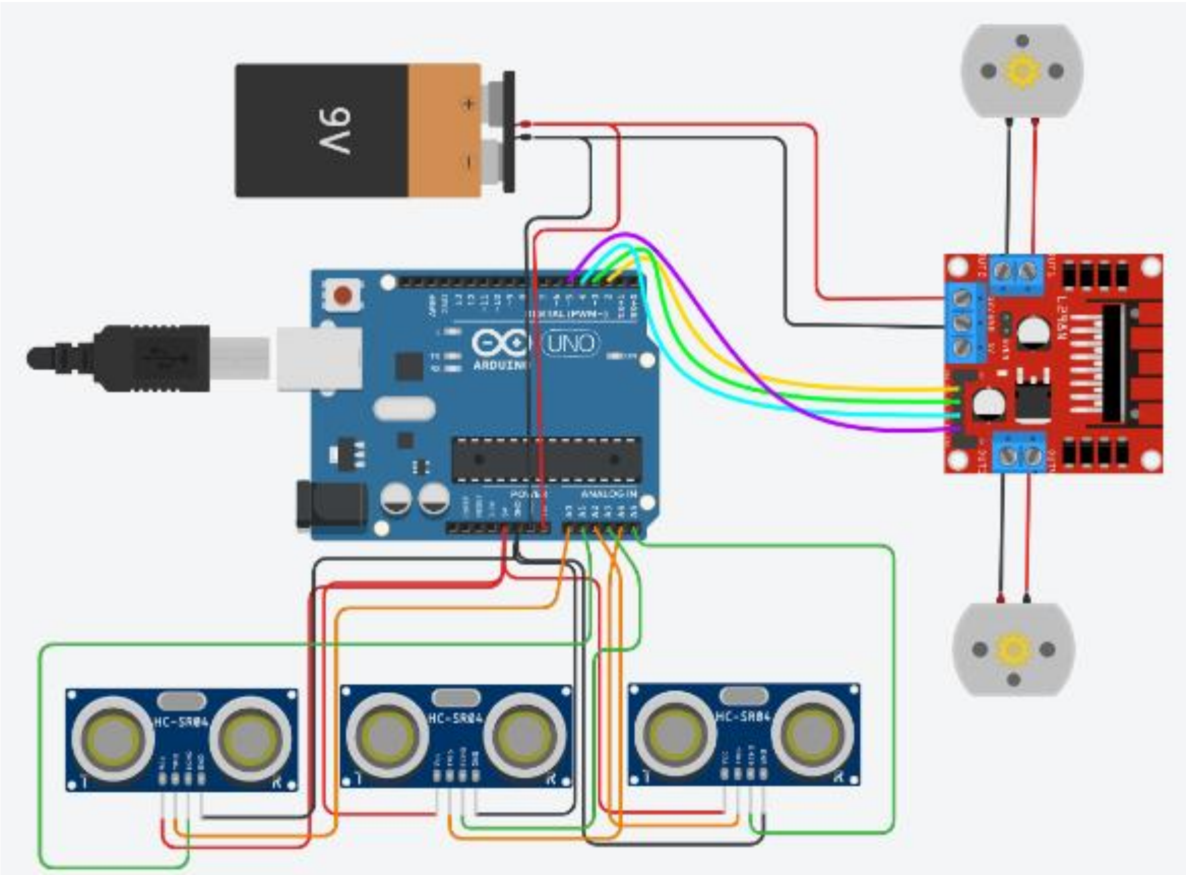

Fig. 3. Wiring diagram

II. Software Development

Regarding the software part, we used two essential libraries for controlling the motors and ultrasonic sensors, namely the "Servo.h" and "NewPing.h" libraries [2]. These libraries provided us with the necessary functionalities to interact with these key components of our autonomous robot.

To control the movement of the motors, we initialized each motor using a specific pin and set a maximum speed for the robot. We also defined and properly initialized the ultrasonic sensors in the code. Using the "Servo.h" library, we assigned a specific role to each pin of the Arduino board, whether it was an input or output, to ensure the correct functioning of the components.

In the next stage, we implemented a function that continuously repeated during the Arduino board's power supply. This function started by reading the values provided by the sensors and calculating the distance in centimeters. Then, we had a series of comparisons between the read distance and the maximum allowed distance, and based on the obtained results, the corresponding movements were initiated to avoid obstacles encountered by the robot.

Throughout the software development process, we encountered a few specific issues. The first problem was related to correctly reading the values from the sensors, and to solve it, we had to repeatedly rewrite the code responsible for reading them. The second issue we faced was accurately instructing the robot and making precise comparisons between the read distance values. This problem was also addressed by repeatedly rewriting the code to achieve the desired results and ensure the optimal functioning of the prototype.

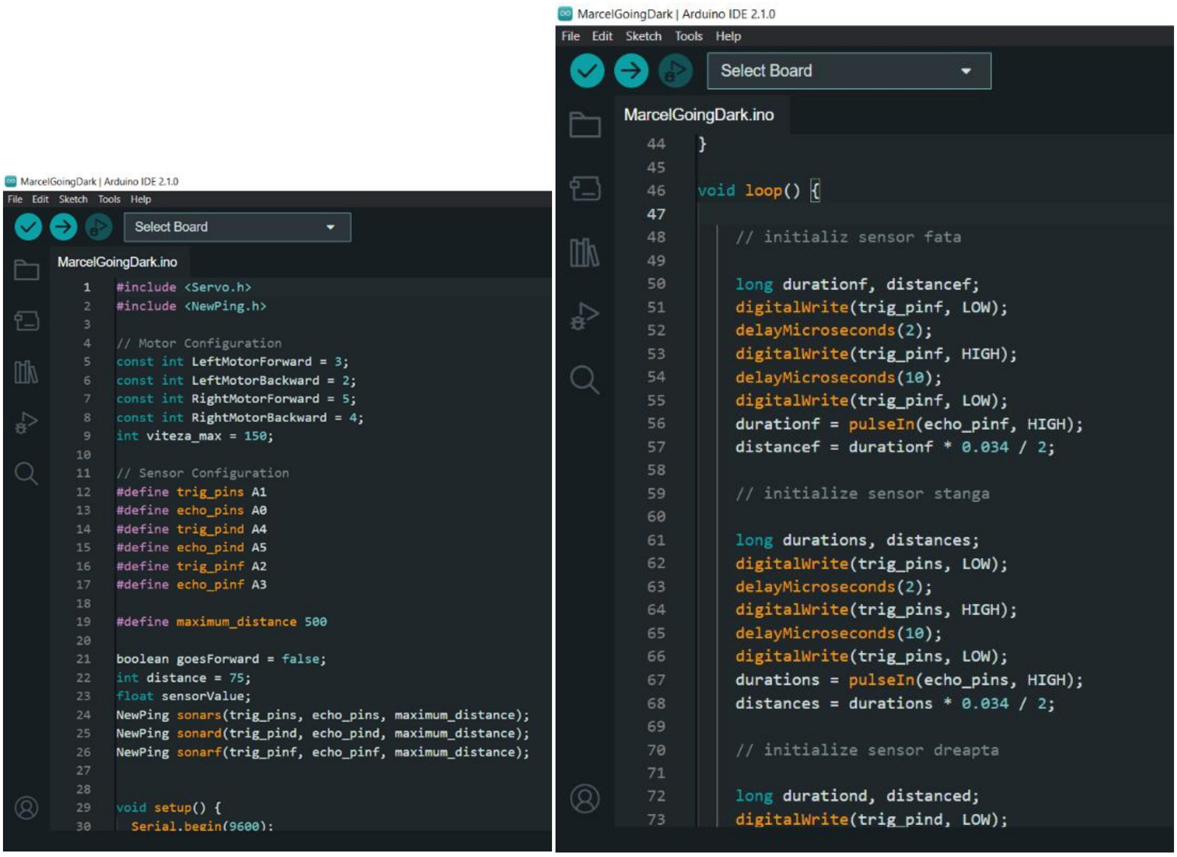

Fig. 4. Lines of code

5. Conclusions

The design and development of an autonomous robot for surface cleaning have been a complex and challenging research stage, where various issues and obstacles were encountered. However, the developed prototype has far exceeded our initial expectations in terms of performance and results achieved.

Nevertheless, it should be noted that the prototype is not without imperfections. A significant aspect is that due to the limited performance of the used sensors, the robot stops at a shorter distance than initially programmed. To address this issue, adjustments were made to the control code parameters. It is important to mention that ultrasonic sensors face difficulties in detecting objects that cannot adequately reflect sound waves. These limitations can be overcome by replacing ultrasonic sensors with infrared sensors, which offer superior capability in detecting and avoiding obstacles.

Thus, the identification and resolution of these issues represent a future research direction to enhance the functionality and performance of the autonomous robot for surface cleaning. By implementing new technological solutions and optimizing control algorithms, we can achieve higher precision and efficiency in the cleaning process, thereby improving the prototype's performance. We have ambitious plans for the future of the project, including a modern navigation system for autonomous and efficient movement, an adaptable cleaning system for industrial applications, improving energy consumption and increasing motor power, as well as implementing a safety system to prevent damage in case of an accident. Additionally, we aim to upscale the product, provide easy replacement of wearable parts and their separate acquisition, and integrate an AI system for automatic learning of new cleaning spaces.

6. Bibliography

[1].https://www.tinkercad.com/dashboard
[2].https://docs.arduino.cc/
[3].https://www.optimusdigital.ro