REVOLUTIONIZING FIREFIGHTING: DEVELOPING ROBOTS FOR RAPID FIRE EXTINGUISHMENT

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ABSTRACT

The development of autonomous systems designed primarily for the detection and suppression of flames has seen a considerable increase in attention in the modern technological environment. The creation of a mobile robot that can be remotely controlled is the innovative approach suggested in this paper for addressing this challenge. The main objective of this research project is to create an adaptable robot by combining the flexible Arduino Uno development platform with the user-friendly LabVIEW graphical programming environment.

Operational capabilities of the robot include a wide range of complex tasks that are necessary for efficiently assisting firefighting activities. It is capable of autonomous navigation, assuring secure movement by carefully avoiding hazards in its way. It also has sophisticated fire detection systems that allow it to quickly detect the existence of a fire. Additionally, it shows proficiency in estimating the distance to the closest obstruction, an essential skill that raises the total operating safety and effectiveness.

Bluetooth technology is used to construct the communication infrastructure that connects the robot to the LabVIEW interface, enabling a smooth method of remote control and real-time monitoring. This paper adds considerably to the development of cutting-edge solutions for fire detection and extinguishment in challenging and complex environments by extensively examining the design, implementation, and performance of the robot.

Keywords: Robotic Autonomy, Fire Sensing, Flame Suppression, LabVIEW Integration, Arduino Control System

I.INTRODUCTION

The development of autonomous, self-sufficient robots with the ability to perform tasks lowers the need for human intervention and is an essential objective in the area of robotics. These robots will be controlled by a computer system and equipped with environmental sensors [3]. Being able to walk around on its own defines a mobile robot, which falls under the general heading of mobile robotics, a branch of robotics and information engineering. These machines belong under the category of autonomous mobile robots (AMR), which refers to machines that can move around freely without the need of physical or electromagnetic directing aids. As an alternative, some mobile robots utilize guidance systems to travel specified paths inside of restricted environments.

The Arduino Uno development board, acting as a processing platform holding thirteen digital inputs/outputs, six analog inputs, and a serial port for peripheral interface, are the fundamental components required for this technological activity. It also has a USB port that makes user interaction easier [2].

- HC-SR04 Ultrasonic Sensor, which provides a practical way to measure the separations between still or moving objects. It touts Arduino compatibility and offers benefits including the use of digital I/O pins, increased noise immunity, and improved accuracy [5].

- LM393 IR Flame Sensor Module, which can detect light sources with wavelengths ranging from 760 nm to 1100 nm and is responsive to both flames and regular light. It interfaces directly with the microcontroller IO port.

A user-friendly Bluetooth SPP (Serial Port Protocol) module precisely created for the quick installation of wireless serial connections is the HC-05 Bluetooth Module.

- L298N Motor Driver is a control device that uses an H-Bridge design to enable simple direction and speed control for up to 2 DC motors.

SG90 Servo Motors are widely utilized in robotics and other applications because of their controllable rotating capabilities. This servo motor has a 180-degree rotation angle and is appropriate for low-power applications.

- H-Bridge L9110s for DC motor are ideal for jobs requiring control of the speed and direction of DC motors.

- DC motor with a 1:48 gear ratio that is ideal to construct mobile robots owing to its wide working voltage range of 3V to 6V and its simple wheel connection.

- A submersible pump that can be integrated with circuit boards, modules, and sensors is the 3-6V Water Pump.

II. HARDWARE IMPLEMENTATION

The robot's wiring diagram was meticulously developed with the Proteus 8 Professional program and made use of existing component models in the hardware development process.

Three sensors were implemented to efficiently detect fires. Their integration was successfully done by connecting them to the analog inputs A0, A1, and A2 on the Arduino Uno board. The 5V output of the board served as the only power source for these sensors. The Arduino's digital pins were also linked to the servo motor and ultrasonic sensor, which were powered by the board's 5V output. Due to the complex nature of this connection, the servo motor's data pin had to be connected to pin 3, the ultrasonic sensor's trigger pin had to be connected to pin 5, and the sensor's echo pin had to be properly connected to pin 4 on the Arduino.Additionally, the integration of the water pump required integration with the H bridge L9110S, which was precisely controlled by the Arduino through digital pins 6 and 7.

The HC-05 Bluetooth device assumed its function in terms of communication, carefully interacting with Arduino through the RX and TX ports. In this configuration, the Arduino's TX pin and the device's RX pin were linked in a reciprocal manner so that the Arduino's RX pin formed a cohesive connection with the device's TX pin. Notably, the 5V output of the L298N module was used to power both the HC-05 Bluetooth device and the H bridge L9110S.

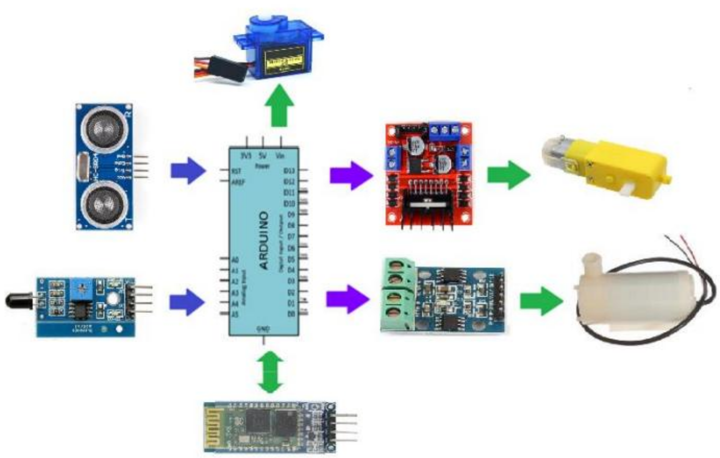

Fig. 1: Essential Components Required for Project Development

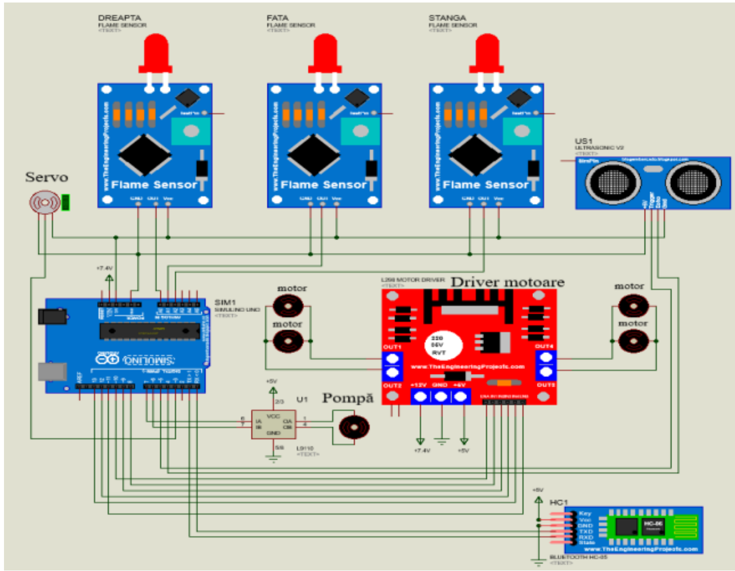

Fig. 2: Schematic Depicting Project Wiring

I strategically decided to design the robot with four wheels in order to maintain structural integrity and functioning. This decision was taken for increased stability as well as to eliminate any possibility of tipping, as seen in Figure 3. The robot has the agility to turn on the spot with the finesse of a crawler robot thanks to the careful pairing of these four wheels in parallel groups of two. The actual framework of the robot was carefully constructed from two acrylic robot chassis parts intended for dual-motor setups. The structural framework of the robot is made up of these two chassis pieces, which were skillfully joined together with a variety of screws and nuts.

For reasons of practicality, the water pump was effectively built into the robot's construction into a separate chamber. As seen in Figure 4, this compartment operated as a functioning water storage, ready to be used in fire-extinguishing procedures.

The Arduino Uno board was carefully set in the middle of the robot, with easy access to its USB connector for possible software upgrades, as seen in Figure 6. I thoughtfully incorporated the HC-05 Bluetooth device, the necessary batteries, and a user-friendly button mechanism for smooth power supply connection and disengagement in the robot's rear area. The robot's operating effectiveness and simplicity of maintenance were ensured by its carefully thought-out configuration and location.

Fig. 3: Visual Aspects of the Robot

Fig. 4: The configuration of Servo Motor and Water Pump

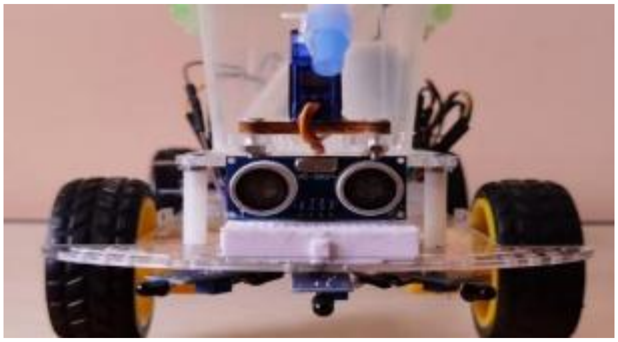

Fig. 5: Sensor Placement

Fig. 6: Overhead View of the Robot

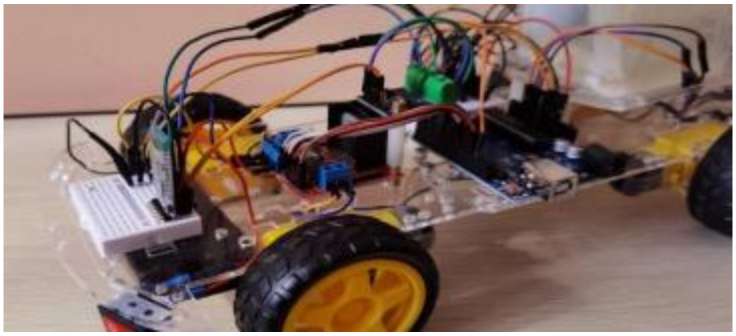

Fig. 7: Back View of the Robotic System

III.MAKING THE CONTROL APPLICATION, IN PART THREE.

To create this autonomous robot, I combined the user-friendly LabVIEW graphical environment with the adaptable Arduino Uno programming platform. These software creations are known as virtual instruments, or VIs, in LabVIEW and have the.vi file extension. These VIs are crucial in the collection and processing of human or computer interface data relevant to the functioning of the robot. They play an essential part in the presentation, storage, and even remote transmission of this data.The robot stands at attention, patiently awaiting orders to carry out the operations written onto the Arduino Uno board, once the crucial link between the robot and our control application has been created. Meanwhile, the robot keeps watch over its sensors, always attentive.

It instantly notifies the control application when certain conditions are satisfied.

For instance, the robot will immediately send a warning message to the control application if the ultrasonic sensor detects an item within 40 cm range (as shown in Figure 10).The warning message will provide the direction from which the fire source was identified if any of the three flame sensors detects a fire.The robot may also be moved manually by the user by pressing the directional buttons (Forward, Backward, Left, and Right) and giving it specific instructions to follow.Users may also define the appropriate motor speeds for the robot, stating them as a percentage, by moving the Speed slider and turning on the Activate button. By just pressing the Pump and Servo button, the robot can also turn on the water pump and servomotor.

Last, but not least, as long as the Distance measurement switch is in the ON position, the robot continuously updates the distance it measures to the closest obstacle.

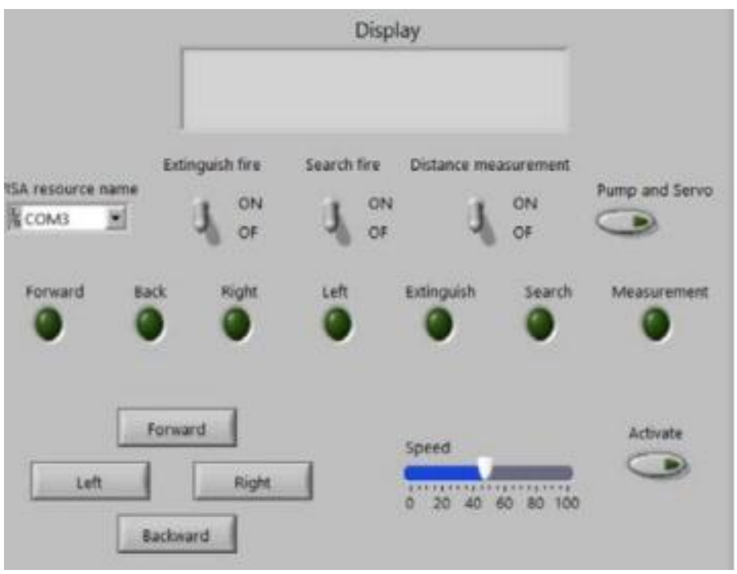

Fig. 8: User Interface on the VI Control Panel

Fig. 9: Connectivity in the Application

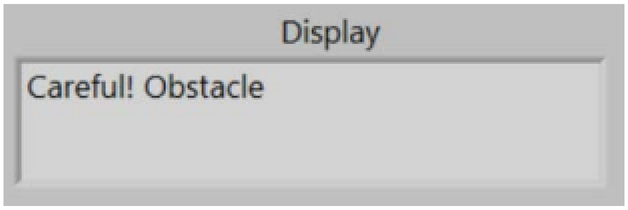

Fig. 10a: Warning for Obstruction Detection

Fig.10b: Alert for Fire Detection

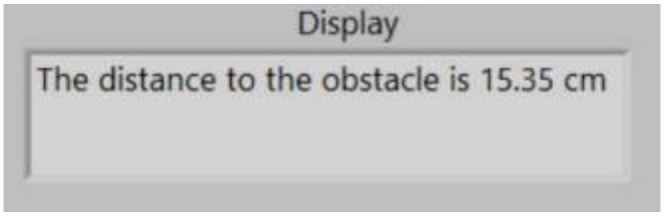

Fig. 11: Incoming Message During Data Collection

IV.CONCLUSION

Robotics is increasingly being used in a variety of fields, including business, transportation, agriculture, the service industry, maritime exploration, and academic study.

The multipurpose autonomous robot we created has several functions, including:

- It efficiently locates and puts out flames.

- It skillfully avoids roadblocks along its route.

- In order to notify impediments or fire sources, it connects with the interface.

- Up until it runs into its first impediment, it keeps in touch with the remote interface.

Particularly in locations with poisonous gases or warehouses that store potentially explosive products during fire disasters, this robot is shown to be a great aid in firefighting, lowering the dangers encountered by firefighters and assuring safety.

REFERENCES

[1] Bogdan, M., „Home Alarm System with Arduino and LabVIEW", Proceedings of the 15th International Conference on Virtual Learning (ICVL 2020), ISSN: 1844-8933 - ISI Proceedings, p. 378-384, OCTOBER 31, 2020

[2] Bogdan, M., „Greenhouse Monitoring and Control of Temperature and Soil Moisture", Proceedings of the 14th International Conference on Virtual Learning (ICVL 2019), ISSN: 1844-8933 - ISI Proceedings, p. 325-331, OCTOBER 25-26, 2019

[3] Nehmzow U., Mobile Robotics, A Practical Introduction, June 11, 2003, ISBN 978-1852337261

[4] https:// www .unitbv.ro/documente/cercetare/doctorat_postdoctorat/sustinere-teza/2014/tarulescu_radu/TarulescuRadu-Rezumat.pdf.

[5] https:// www .optimusdigital.ro/ro/senzori-senzori_ultrasonici/9-senzor-ultrasonic-hc-sr04-.html

[6] N. Sathiabalan Autonomous robotic fire detection and extinguishing system, International Conference on Man Machine Systems (ICoMMS 2021), doi: 10.1088/ 1742- 6596/2107/1/012060