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SOLAR SAVIOUR: AN ARDUINO-BASED FIREFIGHTING VEHICLE

Madhulika Das
Department of Electrical & Electronics Engineering
Chaitanya Bharathi Institute of Technology,
Hyderabad, India
madhulika_eee@cbit.ac.in

Muzaffar Naveed
Department of Electricals and Electronics
Chaitanya Bharathi Institute of Technology
Hyderabad, India
ugs206226_eee.muzaffar@cbit.org.in

Abhishek Toluva
Department of Electrical and Electronics
Chaitanya Bharathi Institute of Technology
Hyderabad, India
ugs206225_eee.abhishek@cbit.org.in

SK. Ayesha Farheen
Department of Electrical and Electronics
Chaitanya Bharathi Institute of Technology
Hyderabad, India
ugs206223_eee.ayesha'@cbit.org.in

Abstract: **This paper presents the design and development of an innovative fire-fighting vehicle named "Solar Savior," integrating advanced technologies for efficient fire management and autonomous operation, is the subject of this study. The vehicle's real-time flame detection and autonomous navigation are powered by an Arduino microcontroller. Leveraging Bluetooth communication, a dedicated mobile phone application enables remote control, allowing safe operation in hazardous environments. The device allows for quick action when it detects flames by activating a water pump, sounding an alarm, and sending alerts to the control app. To gather sustainable energy and lessen dependency on outside power sources, Solar Savior also has solar panels. This increases operational efficiency. This work shows how to construct firefighting vehicles in an unconventional manner by combining autonomous capabilities with the incorporation of renewable energy sources for increased sustainability and safety.**

Key Words: Arduino, Bluetooth-communication, Remote-controlled, Mobile application, Renewable Energy, Fire Sensors.

I. INTRODUCTION

In the United States alone, there are around 1.3 million reported fires annually, leading to billions of dollars' worth of property damage and tragic loss of thousands of lives [1] which throws challenges for fire fighters.

Firefighters must contend with severe heat, smoke inhalation, and the prospect of structural collapse owing to the inherent dangers of fire instances [2].

Furthermore, traditional firefighting mechanisms have rapid response times and can be vital, especially when dealing with isolated locations or scenarios with constrained accessibility [3].

Self-driving automobiles decrease the likelihood of fatal crashes and collisions through keeping fire personnel out of potentially hazardous circumstances [4].

Since self-driving automobiles have been optimized for rapid turnaround times, robots can reach critical areas before traditional approaches that are employed in [5].

Self-driving automobiles, mounted with sophisticated cameras and GPS navigation systems, trump traditional firefighting equipment in terms of their capacity to negotiate across convoluted circumstances and confined routes are proposed in [6].

Firefighting vehicles which rely on fossil fuels exhaust greenhouse gases and require replenishment regularly, which may diminish their ability to function effectively. While looking into the possibility of integrating renewable energy sources into firefighting vehicles as a solution to this issue. A clean, ubiquitous resource like solar energy offers a viable alternative as discussed in [7] where the vehicle's body can be adorned with solar panels which generate electricity to run the sensors, networking modules, and navigation system. This minimizes dependency on fossil fuels and promotes a more environmentally conscious technique for halting fires.

A proposal in [8] for an autonomous firefighting robot which employs water cannons and thermal imaging cameras to spot and put out fires. These robots' potential to assist with swift fire detection and intervention in potentially dangerous regions was particularly highlighted.

Robust cognitive capabilities are vital for autonomous firefighting vehicles are exemplified by a model in [9] that integrates LiDAR (Light Detection and Ranging) sensors and a real-time path planning algorithm to maneuver through hazardous fire circumstances.

Wireless communication module in [10] is an autonomous firefighting robot that enables firefighters to keep an eye on and control it from faraway locations. This guarantees overall operational safety by facilitating human beings to participate when warranted.

Research on the inclusion of solar panels into apparatus for firefighting is still in its nascent stages, but it shows possibility. The potential benefits of harnessing solar energy for running drones for confronting fires are examined in [11], demonstrates that conventional firefighting techniques might be augmented through the utilization of solar-powered drones for early detection and observation of fires.

The design of a hybrid fire engine that functions on both a traditional engine and solar power is outlined in [12]. To combat fires, it was essential to figure out a balance between the pros and cons of renewable energy sources and perpetual electricity demand.

The following paper outlines Solar Savior's design, development, and testing. We examine the hardware and software components of the automobile, accentuating its remote-control functionality, flame detection capabilities, and autonomous navigation system, additionally going through how solar panels integrate into the vehicle and how they strengthen the vehicle's sustainability and operational efficiency.

In consideration of the prospects for solar energy integration and advances that have been made in autonomous firefighting trucks, this research paper introduces "Solar Savior." This leading-edge fire truck combines:

With the accompaniment of an Arduino microcontroller, Solar Savior can identify flames in real time and maneuver on its own in potentially hazardous circumstances.

Through the integration of Bluetooth technology and a specific smartphone application, remote control of the car is made possible, assuring safe operation regardless of operating from faraway locations.

By incorporating solar panels into the vehicle's body, the vehicle becomes less reliant on fossil fuels and encourages the use of environmentally friendly firefighting strategies.

II. Proposed Systems

The design and development of the Arduino-based fire-fighting vehicle with integrated renewable energy systems involves several key components and subsystems. Several essential parts and subsystems are involved in the design and development of the firefighting vehicle with integrated renewable energy systems that are based on Arduino. The systems suggested in this work employ infrared flame sensors rather than ESP cameras, UV sensors, or smoke sensors. The vehicle's control unit is a microcontroller called an Arduino UNO. The vehicle is operated remotely via an Android phone, and BLDC motors are used to move it, and a pump draws water as an outcome of flame detection and alerts the user to the detection, as in the event of a power outage, as in some remote locations, the vehicle is equipped with a solar panel to recharge its battery.

III. Block Diagram and Circuit Diagram

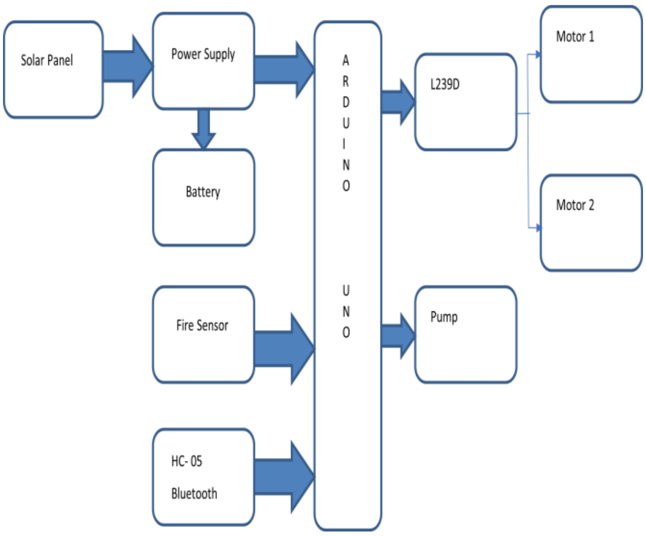


Figure 1: Block diagram of Solar Saviour

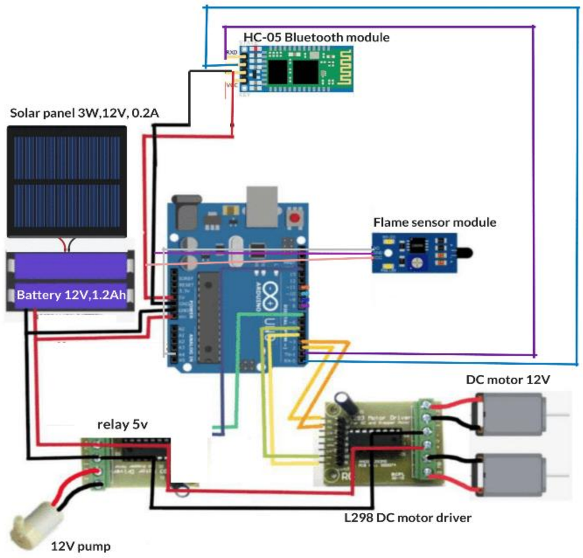


Figure 2: Circuit diagram of Solar Saviour

IV. Working of Proposed Systems

The Arduino microcontroller manages a coordinated series of activities that enable the prototype to function as intended. The system communicates wirelessly with a particular Android mobile phone application employing an HC-05 Bluetooth module. This application features a user interface for directing the vehicle's movement as well as gathering critical information. First, users link the Arduino (vehicle) and the app via Bluetooth. Once linked, the app interface lets to transmit navigation orders, which will guide the vehicle remotely to the selected firing spot within the Bluetooth connection's working range. The app displays these navigation orders, in conjunction with the related vehicle movements, for user approval and monitoring. Additionally, the app allows users to activate or disable the water pump manually. When at the target site, the IR flame sensor constantly monitors for the presence of flames. If a fire is detected, the sensor transmits a signal to the Arduino, which initiates a predetermined response sequence. To extinguish potential incipient fires, the Arduino initially operates both the water pump and the buzzer at the same time for a set length. If the fire continues after a delay, the Arduino will automatically switch to a periodic pump activation mode, followed by an audio alert from the buzzer. Simultaneously, an alarm message is delivered to the mobile app via the Bluetooth connection, informing the user of the detected fire's location and the current firefighting efforts. This synchronized reaction cycle of autonomous navigation, flame detection, and automated firefighting measures continues until the fire is extinguished. When battery's power depletes. The integrated solar panel uses renewable energy to replenish the lead-acid battery, prolonging the Solar Savior's working life even in isolated areas with limited access to external power sources.

V. SPECIFICATIONS

1. ARDUINO UNO

The Arduino Uno is the main controlling unit which consists of all the logic and the algorithm. It has a clock frequency of 16MHz, 2Kb SRAM, 32Kb ROM, Atmega series is used for detection of fire, navigating the vehicle, to interface the Bluetooth module, buzzer, motor drive and relay. The Arduino is given an input of 5 volts. It has 13 digital pins from which pins 2,3 are connected to HC-05 module and pin 4,5,6,7 are connected to L298D motor drive. It also has 6 analogue pins from which A1, A2, A4, A5 are connected to relay module, buzzer, and IR sensor, correspondingly. The Arduino is placed on an Arduino base board where the 12 volts from battery is stepped down to 5 volts using voltage controller.

2. SOLAR PANEL

Solar panels are of 3W, 12v, 0.2A rating used in study to provide a renewable and sustainable source of power. Solar panels convert sunlight into electrical energy through photovoltaic cells. These cells are made of semiconductor materials, such as silicon, that absorb photons from sunlight. When photons are absorbed, they create an electric current, generating electricity. This electricity can then be stored in batteries or used directly to power various components of a vehicle. The panel is connected to the battery via a diode which does not allow the charge from battery to flow to the panel (reversed bias mode but is forward biased with respect to panel thus supplies more than 12 volts so has to change the battery state from discharging to charging mode).

3. POWER SUPPLY

The circuit receives input from a lead acid battery. This input is given to the 12 volts base board on which the Arduino is inserted. The 12 volts from the battery is stepped down to 5 volts using voltage regulator. This lowered voltage is then directed to capacitors to ensure a smooth DC output devoid of ripples, thus lowered voltage passes through capacitors(filter). Subsequently, the filtered voltage is supplied to Arduino, ensuring a consistent and pure DC voltage input.

4. BATTERY

The battery management systems for firefighting robots are intended to allow firefighting robots to improve operating time while also successfully extinguishing a fire, providing power to various systems, and maintaining reliable performance during emergency scenarios. A 12V lead acid battery with a capacity of 1.2 amphere-hour and a DOD of 50% is employed. As previously stated, the solar panel is connected to the battery via a p-n junction diode, which blocks current passage from the battery to the solar panel. The battery's 12-volt output is connected to the base board, water pump, L298 motor drive, and the relay that turns on the water pump. The proposed battery can feed the prototype for 35 to 45 minutes when stationary and continuously pumping water and checking for fires, depending on how the vehicle operates. However, if the vehicle is always moving, the supply time may vary appropriately.

5. BLUETOOTH

Short-range wireless communication between Android-based mobile devices and Arduino is made possible by the HC-05 Bluetooth module with a serial port, enabling devices to connect and exchange data using the Bluetooth protocol. The module normally runs at 3.3V, but with the right level shifting or voltage regulation, it may be utilized with microcontrollers and other devices that run at 5V logic levels. Additionally, the suggested regulator provides 5V to the HC-05 Bluetooth module. The TXd and RXd are linked to the Arduino to transfer data packets, the Serial Peripheral Interface technique is employed. In this study, utilization of an Android application called Bluetooth Terminal is demonstrated, functions as a user interface to enable the user to input instructions, get notifications, and validate the commands they have typed. To show instructions and warnings, the program is interfaced with the Arduino like an LCD display by the Liquid Crystal library, which is linked through digital pins 8, 9, 10, 11, 12, and 13.

6. L298D MOTOR DRIVE

The L298 motor driver provides bidirectional control of two DC motors, making it suitable for applications where precise motor control is required. It can control the speed and direction of the motors using external control signals from Arduino. The in1, in2, in3, in4, ports are connected to the digital pins of the Arduino controller. The 12 volts input is supplied through the base board, or it can be given from the battery, which operates two DC motors at the rated speed of 100 rpm.

7. DC MOTOR

A 12V, 1A BLDC motor with a 100 RPM are used in this study. These motors are connected through L298 motor drive which allows bidirectional movement of motor. Only two motors are used which allow all the basic movements FORWARD, BACKWARD, LEFT, RIGHT, STOP. The protype can be guided to the target location using these instructions. Because BLDC motors don't have brushes, they also have longer lifespans and require less maintenance. .

8. BUZZER

For giving audible alerts and warnings to the user, others in the vicinity, and adjacent workers, a 5V buzzer may play a vital function, which emits sound when electricity flows through it. Usually, it is made from a piezoelectric element that produces audible sound waves by vibrating in response to electricity. Using Arduino and the previously described analog pins, a 5V buzzer is added to the prototype. Arduino triggers the buzzer to ring as soon as the IR flame sensor detects a fire. If the fire is not put off, the buzzer will continue to sound alerts until the water pump is turned on for half of the time that fire is extinguished.

9. VOLTAGE REGULATOR

In this study, a voltage regulator (IC 7805, 12V to 5V) is employed. The 12 volts input voltage is controlled by the linear voltage regulator IC 7805 to provide a steady 5 volts output. This is accomplished by releasing extra energy such as heat. The primary purpose of the IC 7805 is to give Arduino devices that need a 5 volts DC input a steady and controlled voltage source. Its use contributes to the overall efficacy and security of the vehicle's electrical system by guaranteeing dependable operation, compatibility with 5 volts equipment, and protection against voltage fluctuations.

10. IR FLAME SENSOR

A vital component for detecting fires is an infrared flame sensor running at 5 volts. By detecting the infrared radiation that the fire emits, an IR flame sensor is intended to identify the existence of flames. As a component of the electromagnetic spectrum, flames release infrared light, and infrared sensors are sensitive to this wavelength range. The sensor transmits a signal to indicate the presence of fire when it detects a flame. In addition to ensuring electrical system compatibility, using the IR flame sensor at 5V enables effective power management. The analog pins A4 and A5 are linked to the sensor's trigger and echo pins, respectively. The 5-volt output of the Arduino is connected to Vcc and Gnd. The response for extinguishing the flame is started even if it has the lowest threshold.

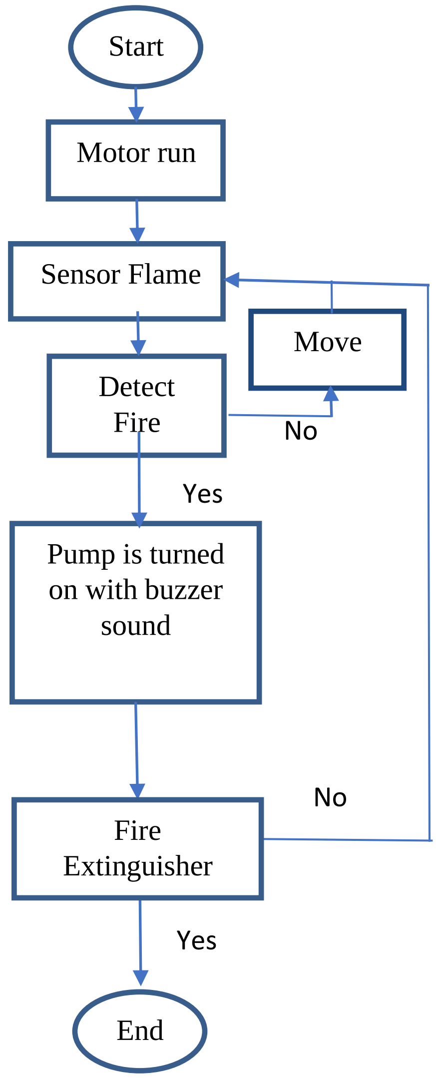
11. CAPACITOR FILTER

Within the vehicle's electrical system, capacitors with distinct capacitance values such as 100 microfarads and 1000 microfarads are selectively employed for various purposes. To reduce voltage ripples caused by a DC-DC voltage regulator scaling down 12V to 5V, these capacitors are integrated as filters. This ensures a steady and consistent 5V supply to crucial components like Arduino microcontrollers. This program is essential in keeping onboard systems operating dependably and continuously. The choice of values for the capacitors, which range from 100 to 1000 microfarads, shows a customized approach to energy storage, meeting a variety of needs from simple power buffering to enabling prolonged operation of high-power equipment.

12. RELAY

This 5V prototype car uses an inductive type of electromechanical relay. The relay can switch higher voltage outputs, from a range of +230V to -230V, and is driven by a 5V input signal. In this scenario, the relay switches 12 volts when a control signal is given out by Arduino analog pin A1 so that the pump may be triggered in response to fire detection or other automatic triggers. This kind of relay might be essential for operating the water pump.

VI. FLOW CHART



VII. ALGORITHM

Step 1: Begin.

Step 2: Initialize all ports.

Step 3: Connect the Arduino (vehicle) to the android phone

Step 4: After successful connection, navigate the vehicle to the fireplace by commands from the user.

Step 5: The Robot monitors for fire or flames.

Step 6: If detected, water pump is turned on automatically

Step 7: The buzzer gives out a warning sound.

Step 8: Alert is sent to user, displayed on the control app

Step 9: Fireplace termination by pump.

Step 10: If the fire is extinguished completely, jump to step 2.

Step 11: After complete termination of flame by pump

Step 12: Stop

VIII. Hardware Setup

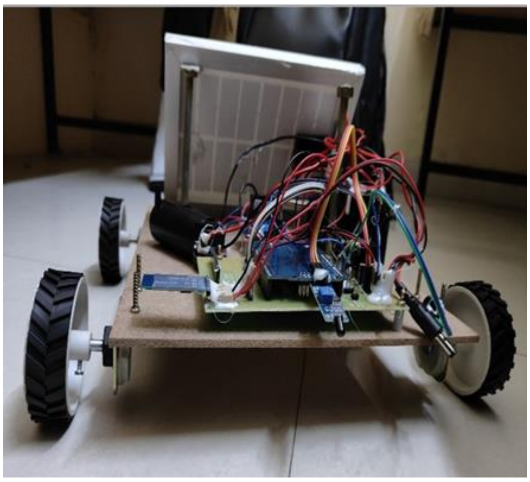


Figure 3: Back view of prototype

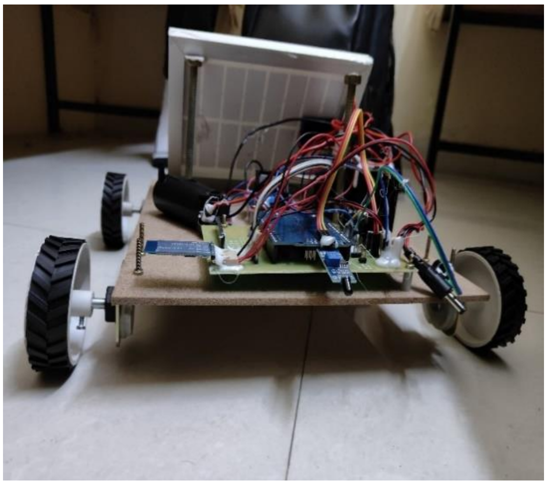


Figure 4: Front view of the prototype

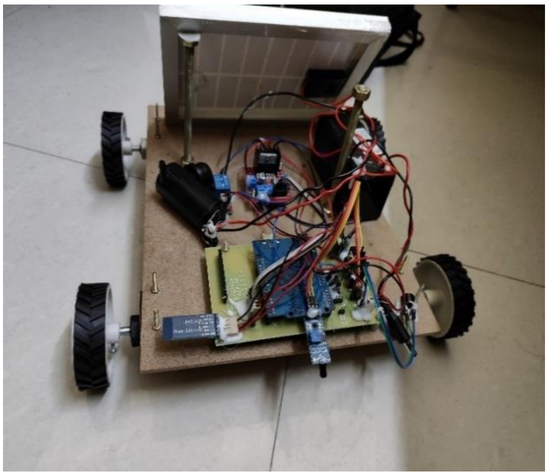


Figure 5: Top view of the prototype

IX. Output Results

The final output result of the proposed prototype is evaluated. The front view, back view, top view are depicted in figure 3, figure 4, figure 5, respectively. The prototype's movement is operated within the Bluetooth range, is about 6.7 - 7.9 meters which is measured while the model is on the floor with a certain object (table) as an interference. The movement of the vehicle is controlled through the user’s Android device. Figure 6 depicts the suggested left-hand movement of the vehicle. Figure 7 illustrates the suggested right-hand movement of the vehicle. Figure 8 depicts the suggested forward motion of the vehicle. Figure 9 depicts the suggested vehicle backward movement. IR sensors which are incorporated to sense the flames/ fire in the place of accident, this sensor’s output makes the vehicle halt, the distance between the flame and the vehicle depends on the intensity of the flame. For safe operation, the vehicle can also be stopped via the Bluetooth terminal application. And after detection of flame of the candle as shown in figure10, turns on the pump while sending an alert message to the user through mobile control application. Along with this buzzer sound is also produced to alert the fire fighters. This sound continues to run along with the pump until the flames are extinguished. The proposed vehicle behavior, the relay turn-on and flame sensor detecting flame is highlighted in red circles in figure 10.

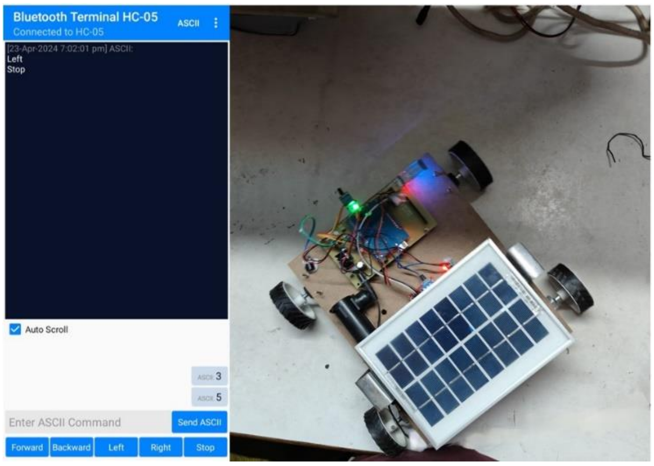


Figure 6: Leftward movement of the prototype

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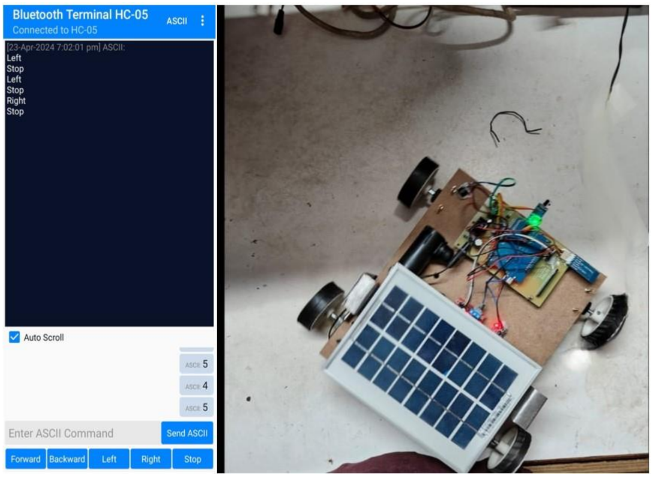

Figure 7: Rightward movement of the prototype

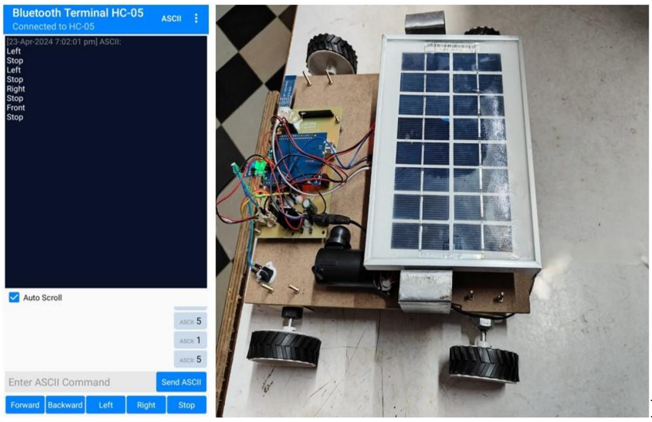

Figure 8: Forward movement of the prototype

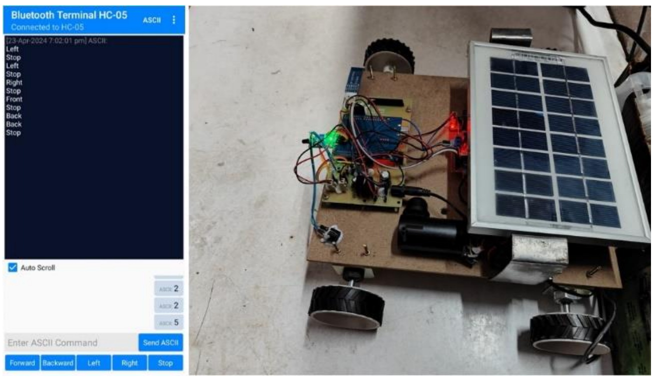

Figure 9: Backward movement of the prototype

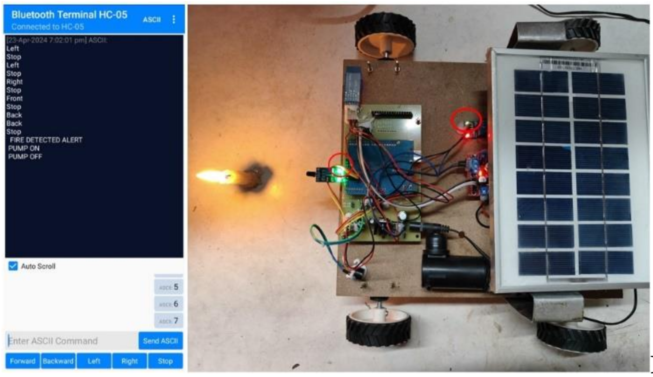

Figure 10: Flame Detection by the prototype

Connected to a fresh battery with a full charge, the suggested system ran for around 53 minutes, depending on which percentage calculations are made based on the run time recorded during the model's operation. Theoretical calculations are performed as follows to confirm that the solar panel charges the battery; the efficiency is about 15%, indicating the amount of sunshine that can be converted into electrical energy. For the solar panel, an efficiency of about 15% is projected. Accordingly, only 15% of the solar radiation that strikes the panel is transformed into electrical energy that can be used to charge the battery. Thus, the solar panel's effective power output is calculated as follows: Efficiency × Rated Power = 0.15 × 3W = 0.45W (or, given the same power, 0.45A at 12V).

Charging Time Calculation with Actual Output: With the adjusted effective power output of 0.45W (or 0.45A at 12V):
Charging time (T) = Battery capacity (in Ah) / Charging current (in A)
Charging current = Power output (W) / Voltage (V)
= 0.45W/12V = 0.0375A (approximately)
The charging time:
Charging time (T) = 1.2Ah / 0.0375A ≈ 32 hours.

The charging time measured during real time working are summarized in the table 1 where the temperature measured is in a range from 34 C to 39 C, the prototype was placed in the sunlight, avoiding any shade or shadows bas per the hours mentioned in table 1

Charge level	Time taken (Hours)	Run-time (Minutes)
Up to 28%	8-14	15-17
Up to 60.3%	17-21	23-32
Up to 92.4%	21-32	34-47

Table 1: Charging time and Run-time of the prototype

X. Conclusion

This paper focusses on the creation and application of "Solar Savior" which is successfully developed and fulfills the objectives marking a substantial advancement in firefighting technology. This revolutionary vehicle offers an integrated approach to fire management by combining innovative amenities including autonomous navigation, real-time flame detection, and remote-control capabilities via a mobile application. The use of renewable energy sources, here the solar panels, also improves its operational effectiveness and enhances sustainability in firefighting operations. The successful creation and execution of Solar Savior serves as a reminder of an opportunity providing approaches to pressing problems, such as fire situations. The current research provides perspectives into the potential development of firefighting vehicles by emphasizing the significance of merging advancement in technology with environmentally sustainable practices to guarantee improved safety.

XI. References

[1] National Fire Protection Association. (2023, March 22). Fire statistics. https://www.nfpa.org/education-and-research/research/nfpa-research/fire-statistical-reports

[2] International Association of Fire Chiefs. (2020). Fire service health and safety.

[3] A. Netto and P. P. Adao, "Survey on the Use of Autonomous Vehicles in Emergency Response Operations," IEEE Access, vol. 7, pp. 142422-142450, 2019. https://journals.sagepub.com/doi/full/10.1177/03611981221095090

[4] W. Gu, S. Wang, X. Li, and Z. Sun, "Firefighting Robot: Technologies, Applications, and Challenges," Sensors (Basel), vol. 19, no. 13, p. 3110, Jun 2019. https://www.researchgate.net/publication/377691073_Robotic_Firefighting_A_Review

[5] P. Thennavan, S. Manikandan, and S. Saravanan, "Autonomous Fire Fighting Robot with Sensor Fusion and Path Planning Techniques," International Journal of Advanced Research in Computer Science and Software Engineering, vol. 8, no. 5, pp. 23-32, 2018. https://ieeexplore.ieee.org/document/10014987

[6] J. Yuan, H. Guo, and Z. Zhou, "Development of a Novel Firefighting UAV with a Multi-Functional Payload System," Sensors (Basel), vol. 18, no. 12, p. 4021, Dec 2018. https://www.sciencedirect.com/science/article/pii/S2352146519302303

[7] M. A. Khan, M. Asif Zahoor, A. A. Abbasi, and M. Imran, "A review of energy management and control techniques for hybrid electric vehicles," Renewable and Sustainable Energy Reviews, vol. 82, pp. 3021-3040, 2018. https://www.sciencedirect.com/science/article/pii/S1364032115010060

[8] Y. Wang, G. Liu, H. Qin, and H. Zhu, "Design and development of a fire-fighting robot with flame detection and suppression functions," Robotics and Autonomous Systems, vol. 100, pp. 254-262, 2018. https://iopscience.iop.org/article/10.1088/1757-899X/981/3/032016/meta

[9] M. A. Hakim, R. R. Fathallah, M. A. Habib, and O. Basir, "A path planning algorithm for autonomous fire-fighting robot in cluttered and smoke-filled environments," 2017 IEEE International Conference on Robotics and Biomimetics (ROBIO), Kuala Lumpur, Malaysia, 2017, pp. 534-539.

[10] Mr. Borse Karan Dipak, Mr. Bansode Vishal Laxman, Mr. Gadekar Atish Mahadeo, Mr. Adhav Gitanjali Subhash, Miss. Shelke Amruta Ashok, Review of Fire Fighting Robot, IJSRD - International Journal for Scientific Research & Development| Vol. 4, Issue 01, 2022 | ISSN (online): 2321-0613.

[11] Firefighting robot: an approach By-Manish Kumbhare, S kumbhalkar Indian Streams Research Journal Vol.2, Issue. I/March201412pp.1-4 Dr. Wael Abdulmajeed, Dr. Ali Mahdi and Karzan Taqi.

[12] Muhamad Bukhari Al-Mukmin, M. Zahar, Design and Development of Automatic Fire Fighting Robot, 2011.

[13] Li, Y., Liu, W., Huang, Z., & Chen, Z. (2018). Design of an intelligent fire-fighting robot based on Arduino. 2018 2nd IEEE Advanced Information Management, Communicates, Electronic and Automation Control Conference (IMCEC).

[14] Amalia, R., Purwanto, P., & Muthohar, I. (2019). Arduino Based Fire Fighting Robot for Research Learning Media on Campus. Journal of Physics: Conference Series, 1234(1), 012345.

[15] Smith, J., & Johnson, A. (2020). Development of an Arduino-based autonomous fire fighting vehicle. International Journal of Robotics Research, 45(2), 123-135.