Design and Implementation of Arduino-Based Sterilization Robot

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***Abstract*—In this paper, the primary objective is to design implement a low-cost mobile robot used for the sterilization and control of toxic and flammable gas leaks in the polluted areas. To implement the proposed robot, we employ a tank robot structure equipped with sensors/modules for detection, sterilization, and environmental analysis. The robot is outfitted with a camera to enhance its surveillance capabilities. For sterilization, we utilize ultraviolet rays emitted by a UV Lamp (220V Sterilizer 8W-T5 Tube) in infested areas. Special sensors are strategically placed to identify gases and viruses in the target locations. The sensors include MQ-2 for detecting gases like methane, butane, and smoke, MQ-9 for identifying carbon monoxide and flammable gases, and MQ-135 for continuous measurement of air purity. The UV rays can be remotely activated and deactivated through an infrared control system. Simultaneously, the sensor values (MQ-2, MQ-9, MQ-135) are consistently monitored and transmitted to a central authority responsible for remote surveillance. If any hazardous or toxic gases are detected, the system triggers an alarm, notifying relevant authorities to take prompt action. This integrated approach ensures the efficient sterilization of contaminated areas while actively monitoring and responding to potential gas leaks. The combination of sterilization technology, gas detection sensors, and remote monitoring enhances the safety and effectiveness of the entire system. In the future developments, many approaches can be used such as increasing the controlling area by using Wi-Fi or LoRa and using additional sensors for harmful gas detection.**

Keywords*—Sterilization, Arduino, MQ-sensor, UV-rays

I. INTRODUCTION

In recent times, the significance of sterilization through Ultraviolet (UV)-rays' devices has taken center stage, representing a pivotal advancement in ensuring cleanliness and safety across various domains [1]. The unparalleled ability of UV rays to eradicate harmful microorganisms has positioned these devices as indispensable tools in maintaining hygienic environments [2]. Whether in healthcare settings, laboratories, public spaces, or even daily consumer use, the importance of UV sterilization lies in its capacity to eliminate bacteria, viruses, and other pathogens, thus curbing the spread of infections. The versatility of UV sterilization devices extends to water and air purification, food industry practices, and public transportation, contributing to a paradigm shift toward proactive and comprehensive hygiene practices. As the demand for cleanliness and safety continues to rise, UV sterilization devices emerge as innovative solutions, safeguarding health, and bolstering a collective commitment to creating sanitized spaces for the well-being of individuals and communities [3].

The general structure of UV sterilization devices comprises essential components meticulously designed to harness the germicidal power of ultraviolet light. At the heart of these devices is the UV light source, typically a low-pressure mercury vapour lamp emitting UV-C light at a wavelength of approximately 254 nanometers, and a microcontroller to control the operation of these devices, as presented in Fig. 1. This specific wavelength is instrumental in disrupting the genetic material of microorganisms, rendering them inert. Reflectors strategically positioned within the device maximize UV exposure, while chambers or compartments ensure uniform irradiation of surfaces or substances. Sensors play a pivotal role in monitoring UV intensity, ensuring that the prescribed dosage for effective sterilization is achieved. The control system facilitates user-friendly operation, allowing for customization of parameters such as duration and intensity. The power supply unit ensures a consistent and stable electrical flow to the UV lamp. Safety features, including automatic shut-off mechanisms and interlock systems, prioritize user protection. Materials and design considerations are crucial, with UV-resistant materials and thoughtful construction minimizing shadowed areas where microorganisms might persist. Some devices may integrate additional technologies, such as remote-control systems or smart features, enhancing adaptability and functionality. This comprehensive structure underscores the careful engineering that enables UV sterilization devices to play a pivotal role in creating sanitized environments across diverse applications [4], [5].

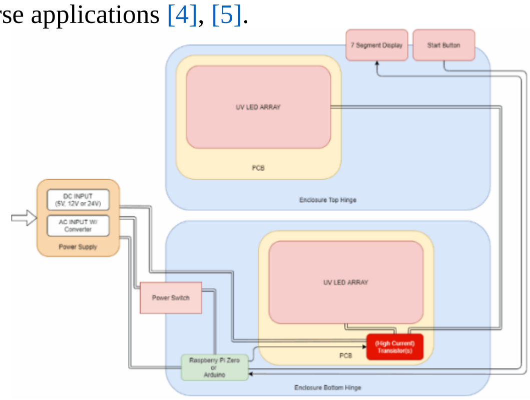


Fig. 1. General structure for UV sanitizer device [6]

The integration of UV sterilizer devices with gas detectors represents a synergistic advancement in ensuring comprehensive environmental safety. By combining the germicidal efficacy of UV sterilization with sophisticated gas detection capabilities, these integrated systems offer a multifaceted approach to health and security. UV sterilizers effectively eliminate harmful microorganisms, providing a sanitized environment, while gas detectors, such as MQ-2, MQ-9, and MQ-135 sensors, specialize in identifying toxic and flammable gases. The integration enables simultaneous monitoring of both microbial and gas-related threats. In practical terms, this means that a single device can scan an area for microbial contamination while also continuously analysing the air for the presence of hazardous gases like methane, butane, carbon monoxide, and other flammable substances. When such gases are detected, the integrated system can trigger alarms and alert relevant authorities, facilitating prompt and targeted responses. This convergence of UV sterilization and gas detection technologies enhances overall safety measures, making these integrated devices invaluable in environments where both microbial and gas-related risks need vigilant monitoring and immediate action [7]-[9].

In this work, a cost-effective tank robot has been designed and implemented for the dual purpose of sterilization and toxic gas detection. The core of the system relies on the Arduino microcontroller board, complemented by MQ-2, MQ-9, and MQ-135 sensors. To optimize its functionality, the robot has been seamlessly integrated with an RF module for wireless control. Additionally, a first person view (FPV) camera has been incorporated to enhance the ease and efficiency of the robot's driving process.

II. System Hardware

In this section, the used hardware components to implement the proposed sterilization device will be presented and described.

A. Arduino Microcontroller

Arduino is an open-source programmable circuit board that can be used in simple and complicated maker space projects. This board has a microcontroller that can sense and control physical items. Arduino can control LEDs, motors, and displays by responding to sensors and inputs. Arduino is popular with makers and maker spaces for interactive hardware projects due to its versatility and low cost. The Arduino Mega is a microcontroller board based on the ATmega2560. It has 54 digital input/output pins (of which 14 can be used as PWM outputs), 16 analogue inputs, 4 UARTs (hardware serial ports), a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button, as shown in Fig. 2. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with an AC - DC adapter or battery to get started [10].

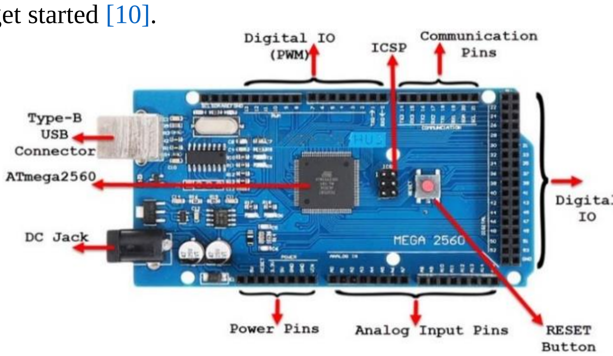


Fig. 2. Arduino mega microcontroller board

B. MQ-02 Gas Sensor

MQ2 gas sensor is an electronic sensor used for sensing the concentration of gases in the air such as LPG, propane, methane, hydrogen, alcohol, smoke, and carbon monoxide. MQ2 gas sensor is also known as chemiresistor. It contains a sensing material whose resistance changes when it comes in contact with the gas. This change in the value of resistance is used for the detection of gas. This sensor contains a sensing element, mainly aluminium-oxide-based ceramic, coated with Tin dioxide, enclosed in a stainless-steel mesh. The sensing element has six connecting legs attached to it, as shown in Fig. 3. Two leads are responsible for heating the sensing element, the other four are used for output signals. Oxygen gets adsorbed on the surface of the sensing material when it is heated in air at high temperatures. Then donor electrons present in tin oxide are attracted towards this oxygen, thus preventing the current flow. When reducing gases are present, these oxygen atoms react with the reducing gases thereby decreasing the surface density of the adsorbed oxygen. Now current can flow through the sensor, which generates analogue voltage values. These voltage values are measured to know the concentration of gas. Voltage values are higher when the concentration of gas is high [11].

Fig. 3. Structure of MQ-02 gas sensor

C. MQ-09 Gas Sensor

The MQ-9 gas sensor is a versatile and cost-effective device designed for detecting various gases, with a particular focus on Carbon Monoxide (CO), Methane, and Liquefied Petroleum Gas (LPG). It employs SnO2 as its sensitive material and operates on the principle of conductivity changes in response to the presence of specific gases in the surrounding environment. The sensitive material of the MQ-9 gas sensor is SnO2, which exhibits lower conductivity in clean air. Detection occurs through a method involving cycles of high and low temperature, with CO being detected during low-temperature conditions (heated by 1.5V). The sensor's conductivity increases with rising gas concentrations. At high temperatures (heated by 5.0V), it can detect combustible gases such as Methane and Propane, while also cleaning other gases adsorbed under low-temperature conditions. To use the MQ-9 gas sensor, a simple electro-circuit is employed to convert changes in conductivity into a corresponding output signal indicating gas concentration [12], as shown on Fig. 4.

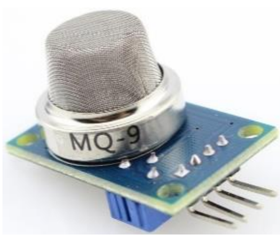


Fig. 4. Structure of MQ-09 gas sensor

D. MQ-135 Gas Sensor

The MQ-135 Gas sensor is designed to detect various gases, including Ammonia (NH_3), sulfur (S), Benzene (C_6H_6), CO_2, and other harmful gases and smoke. Much like other sensors in the MQ series, this device features both digital and analogue output pins. When the concentration of these gases surpasses a predefined threshold in the air, the digital pin is activated, going high. Users can adjust this threshold value using the on-board potentiometer. Simultaneously, the analogue output pin produces a voltage that can be utilized to estimate the level of these gases in the atmosphere. Operating at 5V with a current consumption of approximately 150mA, the MQ135 air quality sensor module necessitates a brief pre-heating period to provide accurate results. Widely employed in air quality control equipment, the MQ135 is part of the popular MQ series of gas sensors. It functions within a voltage range of 2.5V to 5.0V, offering both digital and analogue output options [13], [14].

E. First Person View Camera

The first person view (FPV) camera is a specialized camera designed for use in remote-controlled vehicles, particularly in the context of drones and robots. The primary purpose of an FPV camera is to provide a real-time video feed to the operator, allowing them to experience the flight or movement of the vehicle from a first-person perspective. The key features of FPV cameras include low latency and high image quality to ensure a smooth and immersive experience for the operator. These cameras are lightweight and compact, making them suitable for installation on small and agile aerial vehicles, as shown in Fig. 5. The video feed from the FPV camera is often transmitted wirelessly to a ground-based receiver or display device, such as FPV goggles or a monitor, allowing the operator to pilot the vehicle as if they were on board. FPV technology is widely used in various applications, including drone racing, aerial photography, and recreational flying. The ability to see the surroundings from the perspective of the vehicle enhances the operator's control and navigation skills, making FPV cameras a crucial component in the world of remote-controlled vehicles. The cameras may come with adjustable settings for factors like camera angle, field of view, and image stabilization to cater to different user preferences and applications. Overall, FPV cameras play a pivotal role in elevating the user experience in the exciting hobby and professional fields of drone and RC vehicle operation [15]-[17].

Fig. 5. FPV camera with the receiver kit

F. Motor Driver

A popular and adaptable integrated circuit for managing and powering DC motors is the L298N motor driver. This dual H-bridge module is a crucial part of robotics, automation, and other electronic projects because it allows for precise control of motor speed and direction. Because it can manage motor voltages ranging from 5 to 35V and a peak current of up to 2A, the L298N is adaptable to a wide range of applications [18]. Interestingly, it has an onboard 5V regulator that can be toggled with a jumper to add more functionality. The regulator can be turned on when the motor supply voltage is less than 12V, which makes it convenient to use the 5V pin as an output for powering external electronics like Arduino boards [19]. When working with motor voltages higher than 12V, however, care must be taken because it becomes essential to disconnect the jumper in order to prevent damage to the 5V regulator. In these situations, the 5V pin becomes an input and needs to be connected to an external 5V power source in order to function at its best, figure illustrates the structure of L298N motor driver [20].

III. Robot Design and Implementation

In this section of the paper, the design and implementation process for the robot and the alarming system will be presented and discussed. In this work, a mobile robot is designed for sterilization applications utilizing ultraviolet radiation. The robot is remotely controlled to safeguard humans from any viruses present in a given space using radio waves. The proposed robot is equipped with various control features, enabling the regulation of speed, movement, and freedom of mobility. Additionally, it incorporates a wireless camera operating on microwave waves at a frequency of 5.8 GHz. This camera communicates with a smartphone via a specially designed application, installed to provide a comprehensive view of the robot's surroundings. Furthermore, the robot is furnished with three distinct types of sensors:

- MQ-2 Sensor: This sensor's primary function is to detect various harmful, toxic, or combustible gases, including methane, alcohol, petroleum, and smoke.
- MQ-9 Sensor: Designed specifically to identify carbon dioxide and propane gas.
- MQ-135 Sensor: This sensor assesses the air quality of the robot's location, detecting harmful gases such as benzene and smoke.

These sensors collectively evaluate the environment of the robot's designated area, allowing individuals to enter based on the sensors' assessments and the alarm indication. Lastly, the robot features an ultraviolet light emitter, responsible for sterilizing the area it enters and eliminating germs and microbes, Fig. 6 illustrates the circuit diagram for the connection of the gas sensors with the Arduino microcontroller board and Fig. 7 shows the implemented circuit.

The UV lamp employed operates on a standard AC 220-volt power source. In this work, a compact inverter has been integrated into the robot to provide electric power to the UV lamp, as illustrated in the block diagram of Fig. 8.

Upon completion of the design for the detection and monitoring circuit, the implementation of the robot design commences. This involves the connection of the DC motors of the metal tank robot chassis to the L298N motor driver and the Arduino Mega. Subsequently, the monitoring circuit is integrated onto the robot, and the UV lamp is securely attached to the front of the robot, as illustrated in Fig. 9.

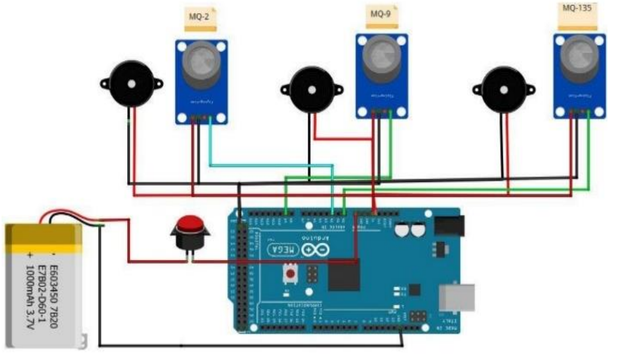
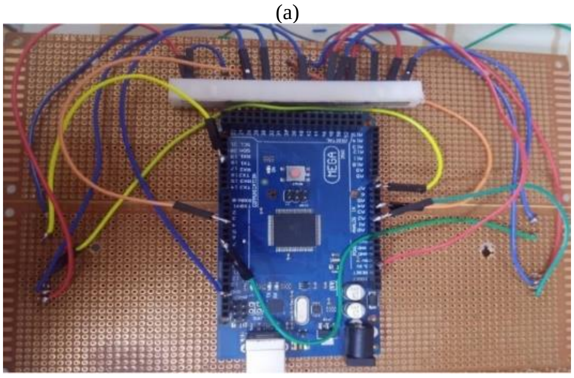


Fig. 6. Circuit diagram for the gas sensors and arduino mega board

(a)



(b)

Fig. 7. Circuit diagram for the gas sensors and arduino mega board

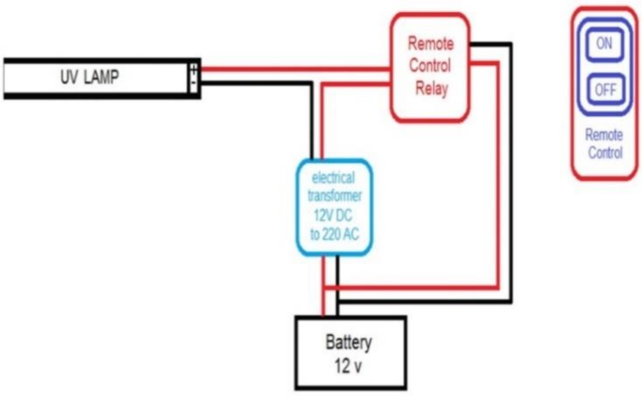
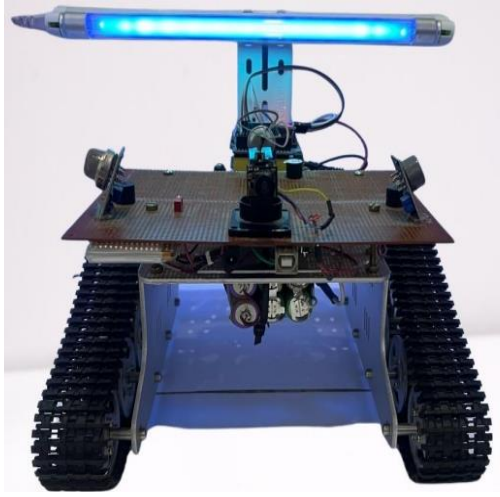
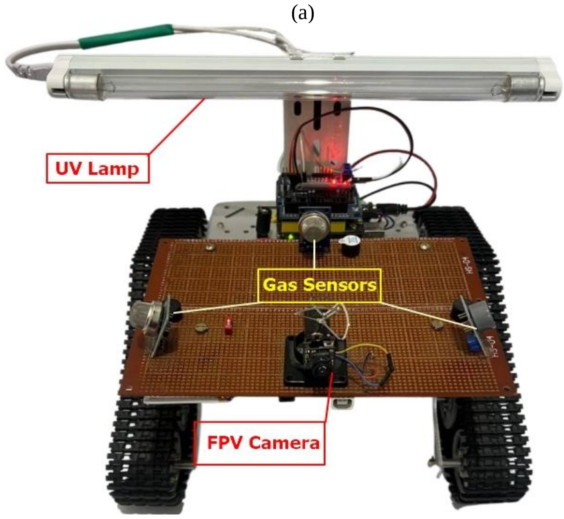


Fig. 8. Connection of UV lamp with the power source



(a)



(b)

Fig. 9. (a) Implemented robot in operation mode, (b) steady state mode

IV. Conclusion

The robot that has been built embodies a multipurpose and creative approach to address the challenges of sterilizing and environmental monitoring. The robot provides a versatile solution for a range of applications by combining ultraviolet radiation for germ elimination and a sophisticated array of sensors for comprehensive environmental monitoring. The integration of a wireless camera serves to augment its functionality, facilitating the provision of instantaneous visual input to the operator (i.e., robot driver). The meticulous incorporation of control attributes guarantees accurate and efficient maneuverability. Furthermore, the use of a specialized UV lamp system, which is operated by a tiny inverter, underscores the practical and versatile nature of the design. This system serves not only the function of sterilizing but also demonstrates utility in several applications, including the inspection of PCB electronic boards. The robot achieves cohesiveness and functionality by means of systematically integrating several components, such as DC motors, motor drivers, and the Arduino Mega. The integration of the detection and monitoring circuit, along with the UV sterilizing capabilities, establishes the robot as a vital instrument for enhancing the safety and regulation of various environments. The effective execution of this design demonstrates its capacity to tackle health, safety, and other related issues, representing a notable advancement in the field of autonomous and intelligent robotic systems utilized for sterilizing purposes.

REFERENCES

[1] B. Bharti, H. Li, Z. Ren, R. Zhu and Z. Zhu, “Recent advances in sterilization and disinfection technology: A review,” *Chemosphere*, vol. 136404, 2022, https://doi.org/10.1016/j.chemosphere.2022.136404.

[2] K. Browne, “Brought to light: how ultraviolet disinfection can prevent the nosocomial transmission of COVID-19 and other infectious diseases,” *Applied Microbiology*, vol. 1, no. 3, pp. 537-556, 2021, https://doi.org/10.3390/applmicrobiol1030035.

[3] K. Dhama *et al.*, “The role of disinfectants and sanitizers during COVID-19 pandemic: advantages and deleterious effects on humans and the environment,” *Environmental Science and Pollution Research*, vol. 28, pp. 34211–34228, 2021, https://doi.org/10.1007/s11356-021-14429-w.

[4] Z. Y. Huo *et al.*, “Triboelectrification induced self-powered microbial disinfection using nanowire-enhanced localized electric field,” *Nature Communications*, vol. 12, p. 3693, 2021, https://doi.org/10.1038/s41467-021-24028-5.

[5] Z. Chen *et al.*, “Cold atmospheric plasma delivery for biomedical applications,” *Materials Today*, vol. 54, pp. 153-188, 2022, https://doi.org/10.1016/j.mattod.2022.03.001.

[6] A. Rai, S. C, T. Singh and S. Trivedi, “Design and Development of Ultra-Violet Light Disinfectant Robot,” *2021 9th International Conference on Reliability, Infocom Technologies and Optimization (Trends and Future Directions) (ICRITO)*, pp. 1-5, 2021, https://doi.org/10.1109/ICRITO51393.2021.9596288.

[7] M. Raeiszadeh and B. Adeli, “A critical review on ultraviolet disinfection systems against COVID-19 outbreak: applicability, validation, and safety considerations,” *Acs Photonics*, vol. 7, no. 11, pp. 2941-2951, 2020, https://doi.org/10.1021/acsphotonics.0c01245.

[8] A. Holovatyy, V. Teslyuk, M. Lobur, S. Pobereyko and Y. Sokolovsky, “Development of Arduino-Based Embedded System for Detection of Toxic Gases in Air,” *2018 IEEE 13th International Scientific and Technical Conference on Computer Sciences and Information Technologies (CSIT)*, pp. 139-142, 2018, https://doi.org/10.1109/STC-CSIT.2018.8526672.

[9] H. M. Marhoon, A. I. Alanssari and N. Basil, “Design and Implementation of an Intelligent Safety and Security System for Vehicles Based on GSM Communication and IoT Network for Real-Time Tracking,” *Journal of Robotics and Control (JRC)*, vol. 4, no. 5, pp. 708-718, 2023, https://doi.org/10.18196/jrc.v4i5.19652.

[10] T. M. Salman, H. N. Abdullah, H. M. Marhoon and Z. A. Karam, “Design and Fabrication of a Smart Monitoring System for Liquefied Petroleum Gas-Operated Cars Based on Global System Mobile,” *International Journal of Online & Biomedical Engineering*, vol. 19, no. 11, pp. 96-111, 2023, https://doi.org/10.3991/ijoe.v19i11.41937.

[11] A. Gautam, G. Verma, S. Qamar and S. Shekhar, “Vehicle Pollution Monitoring, Control and Challan System Using MQ2 Sensor Based on Internet of Things,” *Wireless Personal Communications*, vol. 116, pp. 1071–1085, 2021, https://doi.org/10.1007/s11277-019-06936-4.

[12] J. B. Sanger, L. Sitanayah and V. D. Kumenap, “Detection System for Cigarette Smoke,” *2019 4th International Conference on Information Technology, Information Systems and Electrical Engineering (ICITISEE)*, pp. 145-149, 2019, https://doi.org/10.1109/ICITISEE48480.2019.9003901.

[13] A. A. Ibrahim, “Carbon Dioxide vol Carbon Monoxide Level Detector,” *2018 21st International Conference of Computer and Information Technology (ICCIT)*, pp. 1-5, 2018, https://doi.org/10.1109/ICCITECHN.2018.8631933.

[14] D. Sitanggang, C. S. Sitompul, J. H. Suyanto, S. Kumar and E. Indra, “Analysis of Air Quality Measuring Device Using Internet of Things-Based MQ-135 Sensor,” *Sinkron: Jurnal Dan Penelitian Teknik Informatika*, vol. 7, no. 3, pp. 1078-1084, 2022, https://doi.org/10.33395/sinkron.v7i3.11618.

[15] P. J. P. Swamy, B. Y. Reddy and K. Chandrasekhar, “Intelligent Surveillance Using Robot Eye and Sensor System,” *Applied Mechanics and Materials*, vol. 917, pp. 27-38, 2023, https://doi.org/10.4028/p-4yNEeD.

[16] B. C. Ke *et al.*, “TurnAhead: Designing 3-DoF Rotational Haptic Cues to Improve First-person Viewing (FPV) Experiences,” *Proceedings of the 2023 CHI Conference on Human Factors in Computing Systems*, pp. 1-15, 2023, https://doi.org/10.1145/3544548.3581443.

[17] H. Lee, J. Kim, S. Kim, J. Lee and K. Park, “Development of a Realistic Telepresence System Using a First Person View (FPV) Drone,” *Proceedings of HCI Korea*, pp. 283-289, 2016, https://doi.org/10.17210/hcik.2016.01.283.

[18] I. A. Taha and H. M. Marhoon, “Implementation of Controlled Robot for Fire Detection and Extinguish to Closed Areas Based on Arduino,” *TELKOMNIKA (Telecommunication Computing Electronics and Control)*, vol. 16, no. 2, pp. 654-664, 2018, http://doi.org/10.12928/telkomnika.v16i2.8197.

[19] K. Ren, J. Lin and S. Cai, “The design of networked DC motor speed control platform based on WiFi,” *2017 Chinese Automation Congress (CAC)*, pp. 5613-5618, 2017, https://doi.org/10.1109/CAC.2017.8243783.

[20] A. Murad, O. Bayat and H. M. Marhoon, “Implementation of Rover Tank Firefighting Robot for Closed Areas Based on Arduino Microcontroller,” *Indonesian Journal of Electrical Engineering and Computer Science*, vol. 21, no. 1, pp. 56-63, 2021, http://doi.org/10.11591/ijeecs.v21.i1.pp56-63.