International Research Journal on Advanced Engineering Hub (IRJAEH)
e ISSN: 2584-2137
Vol. 02 Issue: 03 March 2024
Page No: 339 - 348
https://irjaeh.com
https://doi.org/10.47392/IRJAEH.2024.0051

Underwater Visible Light Communication for Scuba Divers Health Monitoring System

Dr.R.T. Ajaykarthi[1], Kamalesh.N[2], Naveen.V[3], Yogeshwaran.B[4]*
[1]*Professor, Mechatronics Engineering, Paavai Engineering College, Namakkal, Tamilnadu, India.*
[2,3,4]*UG, Mechatronics Engineering, Paavai Engineering College, Namakkal, Tamilnadu, India.*
Emails: *ajaykarthik2009@gmail.com[1], kamaleshnt2003@gmail.com[2], nvnaveen02@gmail.com[3], yogeshwaran80820@gmail.com[4]*
****Corresponding Author Orcid ID:*** *https://orcid.org/0000-0002-6645-3008*

Abstract
Diving has become a common way of performing research in the underwater living world. One of the major problems with diving is the health issues faced by the divers during diving and there comes the need for monitoring diver's health. This paper mainly focuses on the health monitoring systems for divers by transferring the data using Li-Fi (Light Fidelity). This system senses different health specifications like heartbeat, body temperature and body position. The monitored health specifications are recorded as a database in a memory chip for further analysis. To reduce the power consumption, the system transfers the data to the nearby divers and ships only during the abnormal health issue. The uniqueness of this system lies in its combination of advanced technologies for diver safety, communication, and submarine surveillance. This is crucial for ensuring their safety, especially in challenging underwater environments. This is perhaps one of the most unique aspects. Li-Fi, which uses light to transmit data, is a breakthrough for underwater communication. This system provides real-time data on the diver's condition and an immediate way to request assistance in case of an emergency. By incorporating temperature and gyro monitoring, the system collects valuable data on diver conditions and movements. This data could be analyzed for research or used to improve safety protocols in the future.

Keywords: *Decentralizing, Stitching, Navigation, Panoramic images.*

1. Introduction
The undersea environment provides a unique and demanding backdrop for human activity, particularly in diving settings. Communication and health monitoring are key components of guaranteeing scuba divers' safety and well-being in such circumstances. Traditional radio-frequency (RF) communication systems are severely limited in underwater environments due to radio wave attenuation and dispersion. Underwater Li-Fi Communication has developed as a possible option in answer to these issues [1].

2. Objectives
Li-Fi, short for Light Fidelity, is a cutting-edge wireless communication technology that transmits data using visible light or near-infrared spectrum. In contrast to typical RF-based systems, Li-Fi has the ability to provide high-speed, secure, and dependable communication in situations where existing approaches struggle. The inherent benefits of light waves, which do not experience the same propagation limitations as radio waves underwater, are taken advantage of by this technique. This project's main objective is to put in place a cutting-edge underwater Li-Fi communication system made exclusively for keeping track of scuba divers' well-being. To offer thorough real-time health information fo rscuba divers, this system integrates several sensors, including an emergency button, a body

International Research Journal on Advanced Engineering Hub (IRJAEH)
e ISSN: 2584-2137
Vol. 02 Issue: 03 March 2024
Page No: 339 - 348
https://irjaeh.com
https://doi.org/10.47392/IRJAEH.2024.0051

temperature sensor, and a gyro sensor. This device claims to revolutionise how scuba divers' health is tracked during underwater operations by utilising an Arduino Uno micro controller for data processing and control. Timely communication is essential in emergency situations [2]. The device includes an emergency button that enables scuba divers to rapidly inform the surface team in case of trouble in order to allay this worry. The capacity to communicate instantly can make the difference between a situation being controllable and developing into a crisis. The system creates an effective and quick communication channel that surpasses the constraints of conventional RF-based technologies in submerged environments by utilising Li-Fi transmitters and receivers. This not only speeds up the transfer of crucial health data, but also enables for rapid response and intervention in the event of an emergency. This project represents an important step forward in underwater safety and operating efficiency. We hope to set a new standard in diver health monitoring and communication by integrating cutting-edge Li-Fi technology with a carefully selected array of sensors and a durable microprocessor. The parts that follow will go over the technical intricacies, components, and operating features of this revolutionary Underwater Li-Fi Communication system.

3. Related Work

1. The planned technique consists of a transmission and receiving section. The transmission section detects the abnormalities moon-faced by the diver and therefore the information is transferred by exploiting the medium referred to as light-weight fidelity. In the receiving section the sunshine signal is reborn within the sort of electrical signal and therefore the information is made within the sort of audio. This can be what we've accomplished with wireless underwater communications.
2. Diving has come a common way of performing exploration in the submarine-living world [3]. One of the major problems with diving is the health issues faced by the divers during diving and there comes the need for covering the diver's health. This paper substantially utilizes Li-Fi (Light Fidelity) data transfer, this system provides divers with health monitoring systems, fear buttons body temperature, and body position.
3. Diving has become a common way of performing research in the underwater living world [4]. One of the major problems with diving is the health issues faced by the divers during diving and there comes the need for monitoring diver's health. This paper mainly focuses on the health monitoring systems for divers by transferring the data using Li-Fi (Light Fidelity).
4. In this paper information correspondence, controlling the gadgets and just as transmission of sound with assistance of noticeable light is accomplished. In an ordinary life, WiFi is utilized as reasonable innovation yet the radiations produced from these are perilous for the strength of human in this way Lifi is liked to the remote advancements like Wifi. Lifi sends the information by utilizing light.
5. Since communications in the Underwater Wireless Sensor Networks (UWSNs) have limited resources and capabilities, designing an efficient and reliable Media Access Control (MAC) protocol for UWSNs faces many challenges [5]. UWSNs have limited bandwidth, power, memory, long propagation delay, high Bit Error Rate (BER), and unreliable communication.
6. Energy consumption is a critical issue in the design of wireless underwater sensor networks (WUSNs). Data transfer in the harsh

International Research Journal on Advanced Engineering Hub (IRJAEH)
e ISSN: 2584-2137
Vol. 02 Issue: 03 March 2024
Page No: 339 - 348
https://irjaeh.com
https://doi.org/10.47392/IRJAEH.2024.0051

underwater channel requires higher transmission powers compared to an equivalent terrestrial-based network to achieve the same range [6]. However, battery-operated underwater sensor nodes are energy-constrained and require that they transmit with low power to conserve power.

7. This paper proposes an application of Li-Fi network in the hospital for monitoring the patient's conditions such as temperature, pressure, heartbeat, glucose level, and respiratory conditions using respective sensors. The collected data from the sensors is transmitted to the sink, and further these data are processed using microcontroller and sent to display unit in the form of graphs or charts. Based on the concept of visible light communication, a prototype model is built with the PIC microcontroller and basic sensors as peripherals and tested it's working [7].
8. In order to solve this many wireless technologies have been proposed to monitor the patient's condition using different sensors but these wireless schemes are harmful for patients/infants and can even interface with medical devices. In order to develop hospital friendly monitoring system, Li-Fi based health monitoring-based system has been proposed which measure the heart rate, temperature and motion in case of infants and the data is continuously displayed on LCD. In case of any abnormalities, the relevant staff will be notified [8].
9. This causes inefficiencies and other issues for a variety of applications, such as ocean exploration and submarine-to-plane communication. To start, there are two choices of underwater communications: Hardwired uses a cable to transfer the data, and wireless uses water for communications. Mostly communicate with land side to transfer their emergency situation we accompanied it [9].
10. Their navigation system is much more challenging than that of land-based applications, due to the lack of connected networks in the marine environment. On the other hand, due to the latest developments in neural networks, particularly deep learning (DL), the visual recognition systems can achieve impressive performance. Computer vision (CV) has especially improved the field of object detection [10].

4. Existing System

Constant monitoring of patient's health condition in hospital is either manual or wireless fidelity (Wi-Fi)-based system. Wi-Fi-based system becomes slow in speed due to exponentially increased scalability. In this scenario, light fidelity (Li-Fi) finds the places wherever Wi-Fi is applicable with additional features of high-speed data network. Apart from the speed factor, Li-Fi is more suitable in hospital applications for monitoring the patient's conditions without frequency interference with human body. This paper proposes an application of Li-Fi network in the hospital for monitoring the patient's conditions such as temperature, pressure, heartbeat, glucose level, and respiratory conditions using respective sensors. The collected data from the sensors is transmitted to the sink, and further, these data are processed using a microcontroller and sent to display unit in the form of graphs or charts. Based on the concept of visible light communication, a prototype model is built with the PIC microcontroller and basic sensors as peripherals and tested it's working [11]. Thus, the application of Li-Fi as a health monitoring system was demonstrated experimentally.

5. Proposed System

A cutting-edge fusion of cutting-edge technology is used in the Underwater Li-Fi Communication system

International Research Journal on Advanced Engineering Hub (IRJAEH)
e ISSN: 2584-2137
Vol. 02 Issue: 03 March 2024
Page No: 339 - 348
https://irjaeh.com
https://doi.org/10.47392/IRJAEH.2024.0051

created for monitoring scuba divers' health. At its core, this system takes advantage of Li-Fi's distinct benefits by transmitting data via the visible or near-infrared spectrum. This development is a game-changer for underwater situations, where conventional radio-frequency (RF) communication meets tough obstacles because of the water's radio wave absorption and scattering. Critical health metrics are continuously and in real-time monitored thanks to the inclusion of an emergency button, a body temperature sensor, and a gyro sensor. By serving as a direct line of communication between the diver and the surface team, the emergency button enables immediate crisis alerting. The the Arduino Uno microcontroller, which orchestrates the flow of data from the sensors and controls communication with the Li-Fi transmitter and receiver. It serves as the system's brain, handling data interpretation, communication protocols, and alarm triggering [12]. Its adaptability and programmability make it an excellent choice for this application, allowing for the easy integration of multiple components. The Li-Fi transmitter and receiver serve as the communication system's backbone. The processed sensor data is converted into light signals by the transmitter, which are subsequently sent across the aqueous medium. This technique has considerable advantages over standard RF-based communication in terms of data transmission speed and security. A strategically placed receiver collects light signals and sends the information to Arduino Uno for additional processing. The timely delivery of health information to the surface team depends on this trustworthy and effective communication link. An LCD monitor is built within the system to give scuba divers a user-friendly interface. This display presents essential health information simply and understandably. Scuba divers can perform quick assessments of their health, enabling them to make wise choices while engaging in underwater activities [13]. Additionally, a bell is activated in an emergency to further notify the surface team. By adding an extra layer of notification with this auditory signal, we can make sure that no urgent issue goes overlooked. The Transmitter Section and Receiver Section are shown in Figures 1 & 2.

6. Block Diagram

6.1 Transmitter Section

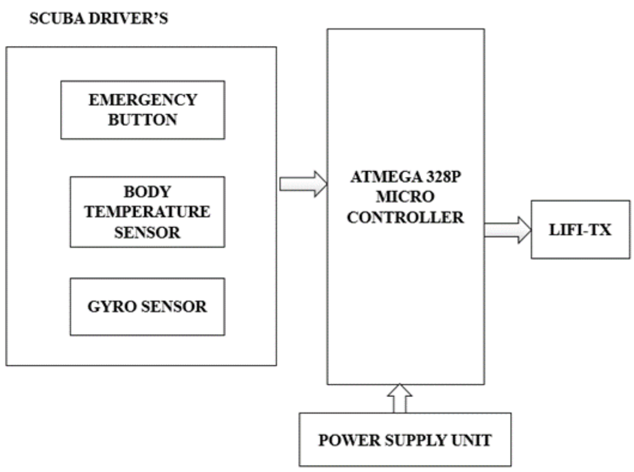

Figure 1 Transmitter Section

6.2 Receiver Section

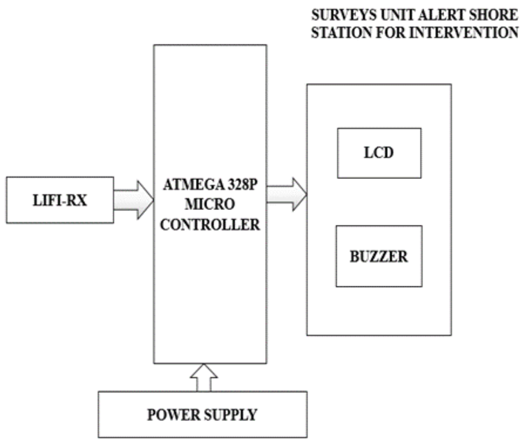

Figure 2 Receiver Section

7. Explanation

The emergency button is an essential component of the system, allowing scuba divers to signal for rapid assistance or alert the surface team in the event of a problem [14]. When pressed, it initiates an immediate connection with the surface station, enabling for quick response in emergencies. The body

International Research Journal on Advanced Engineering Hub (IRJAEH)
e ISSN: 2584-2137
Vol. 02 Issue: 03 March 2024
Page No: 339 - 348
https://irjaeh.com
https://doi.org/10.47392/IRJAEH.2024.0051

temperature sensor is a precision gadget that measures the core body temperature of the diver. It gives real-time data on the diver's physiological state, assisting with the detection of overheating and hypothermia. This information is critical for the diver's safety during extended underwater tasks. The gyro sensor, senses the scubas movement to update on the microcontroller. The system's central processing unit is the Arduino Uno microcontroller. Receiving data from the various sensors, processing it, and managing communication with the Li-Fi transmitter and receiver are its duties. The microcontroller furthermore carries out the logic for deciphering emergency signals from the button and turning on the alarm system. A specialized component that turns processed sensor data into modulated light signals is the Li-Fi transmitter. These signals convey encoded data and are transferred via the water medium. The transmitter overcomes the limits of standard RF communication in underwater situations by utilizing visible light or near-infrared spectrum, enabling a high-speed and secure data transfer channel. The Li-Fi receiver is strategically placed to receive the light signals transmitted by the Li-Fi transmitter. It is in charge of demodulating and retrieving encoded data, which is subsequently sent to the Arduino Uno microcontroller for processing. The sensitivity and precision of the receiver are critical for maintaining reliable transmission. Scuba Divers can obtain their real-time health data using the LCD's user-friendly interface. It shows crucial metrics like body temperature and activity level, enabling scuba divers to keep an eye on their well-being while performing underwater operations. This element is essential for empowering and preserving scuba divers' knowledge. When an emergency arises, the buzzer can be used as an auditory alert system. It generates a distinct sound when activated to notify the surface crew, adding another layer of notice to the LCD's visual cues. This auditory indication is necessary to make sure that urgent problems are handled right away. The power Supply Unit is shown in Figure 3.

8. Hardware Requirements

8.1 Power Supply Unit

A power supply unit (PSU) is an important component in electronic devices that converts electrical power from an external source (such as a wall outlet or a battery) into a form that can power the device's internal components. It supplies the required voltage, current, and stability to ensure that electronic circuits operate properly.A power supply unit frequently incorporates circuitry to adjust the voltage output. This ensures that, even if the input voltage varies, the voltage provided to the device remains consistent. This is critical for the reliable operation of delicate electrical components. Power supplies are often equipped with safeguards that limit the amount of electricity that can be pulled from them [15]. This avoids overloading and potential damage to the power source or associated devices. Some power supplies have numerous outputs with varying voltage and current ratings. This is useful for powering devices with varying power needs.

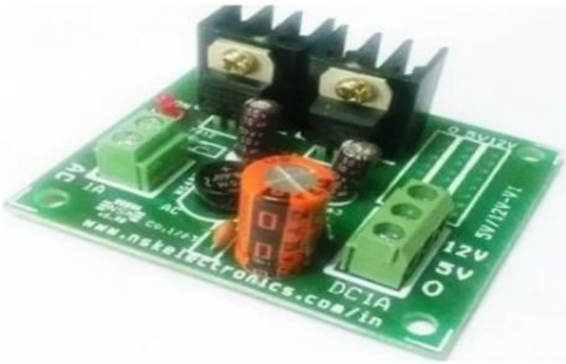

Figure 3 Power Supply Unit

8.2 Arduino Uno

In the field of electronics and embedded systems, the Arduino Uno microcontroller board is a flexible and popular choice. It was created by Arduino and is based on the ATmega328P microcontroller, providing a robust yet user-friendly platform for many projects. As a result of the board's numerous digital and analogue input/output pins, it can connect to a large range of sensors, actuators, and other parts. Its simplicity in programming, which can be

International Research Journal on Advanced Engineering Hub (IRJAEH)
e ISSN: 2584-2137
Vol. 02 Issue: 03 March 2024
Page No: 339 - 348
https://irjaeh.com
https://doi.org/10.47392/IRJAEH.2024.0051

accomplished using the Arduino Integrated Development Environment (IDE), which streamlines the process with a user-friendly interface, is one of its distinguishing qualities. This makes it a fantastic option for both novice and seasoned developers. The Arduino Uno's adaptability and flexibility make it suited for a wide range of applications. Prototyping, automation, robotics, IoT (Internet of Things), and educational projects are all typical uses for it. Its compatibility with a large selection of shields (add-on boards) and libraries makes it simple to extend its capabilities, allowing for the smooth integration of extra functionalities. Furthermore, its low cost and widespread availability make it an appealing option for both enthusiasts and educational organizations. The Arduino Uno, with its user-friendliness, expandability, and robustness, remains a cornerstone in the field of embedded electronics, enabling innovation and creativity in innumerable projects throughout the world. Arduino Uno is shown in Figure 4.

Figure 4 Arduino Uno

8.3 Lifi Transmitter

A Li-Fi transmitter is a device that transmits data wirelessly by using light waves, often in the visible or near-infrared spectrum. The wireless communication system known as Li-Fi, or "light fidelity," has a number of benefits over more established radio-frequency (RF) communication techniques. A Li-Fi transmitter modifies data onto light waves, which a Li-Fi receiver may pick up and demodulate in order to extract the data that was sent. High-speed and secure data transfer is made possible by this technology, which is especially helpful in conditions where RF communication may be difficult, as in the water or in places with electromagnetic interference. Li-Fi transmitters are used in a variety of industries, such as secure data transmission in delicate settings, indoor locations, and underwater connections. Li-Fi Transmitter and Li-Fi Receiver are shown in Figures 5 & 6.

Figure 5 Li-Fi Transmitter

8.4 Lifi Receiver

A Li-Fi receiver is a device that captures and decodes modulated light signals sent by a Li-Fi transmitter. Li-Fi, or Light Fidelity, is an innovative wireless communication technology that transmits data using visible light or near-infrared spectrum. The receiver is outfitted with specialised sensors or photodetectors that detect light signals and transform them back into electrical data. This enables the receiver to retrieve the data sent by the Li-Fi transmitter. Li-Fi receivers are critical in providing high-speed and secure wireless communication, particularly in areas where standard radio-frequency (RF) transmission may be limited. They are used in fields such as underwater communication, indoor positioning systems, and secure data transfer in sensitive environments.

International Research Journal on Advanced Engineering Hub (IRJAEH)
e ISSN: 2584-2137
Vol. 02 Issue: 03 March 2024
Page No: 339 - 348
https://irjaeh.com
https://doi.org/10.47392/IRJAEH.2024.0051

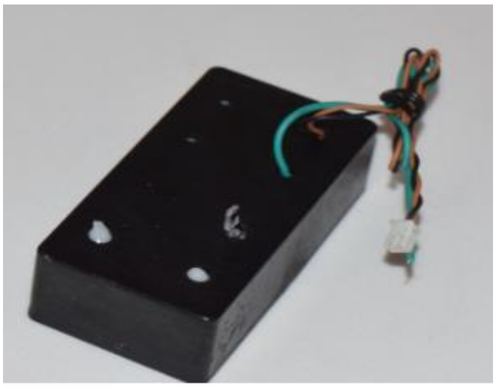

Figure 6 Li-Fi Receiver

8.5 Emergency Button

Figure 7 Emergency Button

The emergency button in the Underwater Li-Fi Communication system for monitoring scuba divers' health is a key safety element that allows scuba divers to signal distress or emergency circumstances to the surface team quickly and effectively. This button, which is placed within easy reach of the diver, provides a direct and immediate way of alerting the surface team in the event of an emergency (Figure 7). When pressed, it sends an emergency signal via the Li-Fi communication channel, which is subsequently received and processed by the surface station. This ability to respond quickly is critical in underwater conditions, where quick action can be the difference between a controllable issue and a potentially life-threatening emergency.

8.6 Temperature Sensor

Figure 8 Temperature Sensor

A specialized electronic gadget is used in the Underwater Li-Fi Communication system for scuba divers' health monitoring to assess the underwater environment's ambient temperature. This sensor is essential for giving the diver's body temperature, an important physiological parameter, in real-time data. The sensor assists in ensuring that the diver stays within a safe temperature range throughout the underwater operation by continuously measuring the diver's body temperature. Based on concepts like resistance change, voltage variation, or semiconductor properties in reaction to temperature fluctuations, the temperature sensor functions. It offers accurate and precise measurements, enabling the identification of even minute variations in the diver's body temperature. This data is then communicated to the surface station via the Li-Fi communication channel, where it can be monitored and analyzed by the surface team. Temperature Sensor is shown in Figure 8.

8.7 Gyro Sensor

A gyro sensor (Figure 9), often known as a gyroscope sensor, is a device that measures rotational motion or angular velocity. It gives information on the rate of rotation about a specific axis. Gyro sensors are essential in a wide range of applications, including aerospace, vehicle stability control systems, electronic devices, and robotics. These sensors operate based on angular momentum. They usually have a rotating mass that resists orientation changes. The Coriolis effect causes the spinning mass to deflect when the sensor experiences angular motion, and this deflection is then measured to calculate the

International Research Journal on Advanced Engineering Hub (IRJAEH)
e ISSN: 2584-2137
Vol. 02 Issue: 03 March 2024
Page No: 339 - 348
https://irjaeh.com
https://doi.org/10.47392/IRJAEH.2024.0051

rate of rotation. Gyro sensors are essential components of electronic devices like smartphones for functions including screen orientation, gaming, and camera image stabilization. They provide for fine control of orientation and movement in robotics. Gyro sensors are essential parts of navigation systems in aircraft applications, ensuring precise location and heading data. In a wide range of dynamic systems, gyro sensors are essential for supplying stability and control.

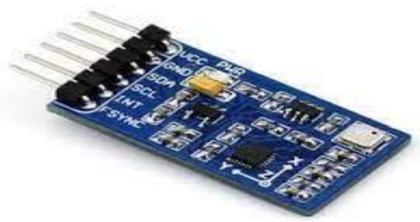

Figure 9 Gyro Sensor

8.8 LCD

Figure 10 LCD

A liquid crystal display, or LCD (Figure 10), is a flat-panel electronic visual display technology that is widely used in devices such as televisions, computer monitors, and different mobile devices. It works by modifying the characteristics of liquid crystals to control the passage of light and so create images or text. LCDs are substantially thinner and lighter than classic cathode ray tube (CRT) displays, making them very adaptable and ideal for a wide range of applications. They use less power, produce less heat, and have exceptional visual clarity. LCDs are made up of pixels, each of which contains sub-pixels that emit red, green, and blue light, resulting in a full range of colors. This technology has become a mainstay of modern visual displays, revolutionizing how information is delivered and viewed in a variety of industries.

8.9 Buzzer

Figure 11 Buzzer

When an electrical current is passed through a buzzer, it produces an audible sound. It is often made up of a piezoelectric element or an electromagnetic coil, as well as a diaphragm. The buzzer emits a distinct sound or tone when actuated. A buzzer is included as a crucial alerting device in the "Underwater Li-Fi Communication for Monitoring Scuba Divers' Health" system. The Arduino Uno microcontroller activates the buzzer to provide a loud and recognizable sound in an emergency or when the diver presses the emergency button. The purpose of this auditory signal is to provide an additional layer of notification to the surface team about the critical underwater condition. It guarantees that the diver's distress signal is adequately relayed even in difficult underwater circumstances, enhancing their safety and hastening any required aid or reaction. A crucial safety component that improves the overall efficiency and dependability of the communication and monitoring system for scuba divers is the buzzer (Figure 11).

Conclusion

Finally, the Underwater Li-Fi Communication system designed to monitor scuba divers' health marks a significant advancement in underwater safety and health monitoring. This system provides a comprehensive solution for real-time health monitoring and emergency communication in demanding underwater situations by integrating cutting-edge Li-Fi technology with a suite of sensors, an Arduino Uno microcontroller, and other critical components. The presence of an emergency button, a body temperature sensor, and an gyro sensor ensures that vehicle data are continuously monitored, allowing for fast response in the event of a crisis. The implementation of Li-Fi technology provides a dependable and fast communication channel that outperforms previous RF-based approaches, considerably improving diver safety. This novel device not only promises to transform how scuba divers' health is handled during underwater operations, but it also establishes a new benchmark for safety regulations in high-risk areas. The Underwater Li-Fi Communication system holds enormous promise for the future of underwater exploration and operations, with the opportunity for further developments and applications.

Reference

[1]. Aditiba Rao, Viral Parekh. "A Survey on Animal Detection Methods used to avoid Animal Vehicle Collision." IJSRD {International Journal for Scientific Research & Development| Vol. 6, Issue 01, 2018 | ISSN (online): 2321-0613

[2]. Divya, Usha Kiran, Praveen M, "IOT- Based Wild Animal Intrusion Detection System", "International Journal on Recent and Innovation Trends in Computing and Communication", ISSN: 2321-8169, Volume: 6, Issue: 7, pp: 06 – 08, 2018.

[3]. Harish Kalla,Balachandran Ruthramurthy,Satyasis Mishra,Gemechu Dengia,Sarankumar R.A Practical Animal Detection and Collision Avoidance System Using Deep Learning Model, IEEE July 2022 10.1109/I2CT54291.2022.9824594

[4]. B. Karthikeya Reddy , Shahana Bano, G. Greeshmanth Reddy , Rakesh Kommineni , P. Yaswanth Reddy. Convolutional Network based Animal Recognition using YOLO and Darknet ,2021

[5]. A. A. Menshikova, A. E. Stepanova and A. A. Menshchikova, "Research on Reduction of AnimalVehicle Collisions," 2021 IEEE Conference of Russian Young Researchers in Electrical and Electronic Engineering (ElConRus), 2021, pp. 545- 549, doi: 10.1109/ElConRus51938.2021.9396238.

[6]. R. Shanthakumari,C. Nalini,S. Vinothkumar,B. Govindaraj. Image Detection and Recognition of different species of animals using Deep Learning ,April 2022.

[7]. Panicker, Shruti Ajithkumar, Rahul Vinod Kumar, Aishwarya Ramachandran, and S. Padmavathi. "Analysis of Image Processing Techniques to Segment the Target Animal in Non-uniformly Illuminated and Occluded Images." In Inventive Communication and Computational Technologies, pp. 15-26. Springer, Singapore, 2021.

[8]. Parham, J., Stewart, C., Crall, J., Rubenstein, D., Holmberg, J., & Berger-Wolf, T. (2018, March). An Animal Detection Pipeline for Identification. In 2018 IEEE Winter Conference on Applications of Computer Vision (WACV) (pp. 1075- 1083). IEEE.

[9]. S. Yadahalli, A. Parmar and A. Deshpande, "Smart Intrusion Detection System for Crop Protection by using Arduino," 2020 Second International Conference on Inventive Research in Computing Applications (ICIRCA), 2020, pp. 405-408, doi: 10.1109/ICIRCA48905.2020.9182868

[10]. Z. Zhao et al, "Object detection with deep learning:A review," IEEE Trans. Neural Netw. Learn. Syst., vol. 30, no. 11, pp. 3212–3232, 2019

[11]. R. Panigrahi et al., "Development of modified gas indices for early detection of spontaneous heating in coal pillars," J. Southern Afr. Inst. Mining Metall., vol. 104, no.7, pp. 367-379, 2004.

[12]. C.Sensö güt, "Spontaneous combustion related fire ratios," Pamukkale Üniversitesi Mühendislik Bilimleri Dergisi, vol. 5, no. 1, 2011.

[13]. S. Ray, R. Singh, N. Sahay, and N. Varma, "Assessing the status of sealed fireunderground coal mines," J. Sci. Ind. Res., vol. 63, pp. 579-591, 2004.

International Research Journal on Advanced Engineering Hub (IRJAEH)
e ISSN: 2584-2137
Vol. 02 Issue: 03 March 2024
Page No: 339 - 348
https://irjaeh.com
https://doi.org/10.47392/IRJAEH.2024.0051

[14]. L. Muduli"Application of wireless sensor network for environmental monitoring in underground coal mines: A systematic review," J. NetwComput. Appl., vol. 106, pp. 48-67, 2018
[15]. P. K. Jana, and D. P. Mishra, "A novel wireless sensor network deployment scheme for environmental monitoring in longwall coal mines," Process Saf. Environ.