Aquatic Incident Detection and Prevention System

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***Abstract*—An innovative underwater incident detection system is introduced to enhance safety in aquatic environments, specifically targeting vulnerable populations such as the elderly and infants. Drowning incidents remain a significant global threat, often leading to severe injuries or fatalities. Conventional detection methods struggle in underwater settings, highlighting the need for specialized solutions. The proposed system utilizes pressure sensors and accelerometers to monitor changes in movement and position, transmitting real-time data to a central control unit. Upon detecting signs of submergence or distress, the system automatically activates safety measures, such as buoyant vests or flotation devices, to provide immediate assistance. Additionally, the system features low-power wireless communication to ensure continuous monitoring without significant energy consumption. Applicable in various underwater scenarios, including recreational areas and hazardous construction sites, this approach aims to mitigate the risk of injuries and fatalities while improving overall safety standards in aquatic environments.**

***Keywords*—Buoyant Vests, Accelerometers, Fall Detection Systems, Pressure Sensors.**

I. INTRODUCTION

Drowning is a global concern, particularly affecting vulnerable populations such as the elderly and infants, often leading to severe injuries and fatalities. To address this critical issue, innovative underwater incident detection technologies have emerged, designed to proactively identify potential drowning incidents and swiftly notify caregivers or emergency services. Traditional detection methods have proven inadequate in aquatic environments, necessitating the development of specialized solutions tailored to these unique settings.

The proposed underwater incident detection system represents a significant advancement in aquatic safety. It utilizes pressure sensors and accelerometers, similar to land-based fall detection systems, to monitor subtle changes in movement and orientation underwater. This real-time data is transmitted to a centralized control unit, which promptly triggers alerts upon detecting submergence or signs of distress. These timely notifications enable the rapid deployment of protective measures, such as activating buoyant vests or flotation devices, potentially preventing serious consequences.

This innovative system is applicable across various underwater environments, from recreational water bodies to hazardous construction sites. By addressing the specific challenges of aquatic safety, it aims to reduce the incidence of injuries and fatalities, thereby improving overall safety standards in these settings. The integration of advanced sensor technologies with proactive alert mechanisms marks a significant step forward in protecting lives at risk of drowning, laying the groundwork for further exploration of the system's capabilities and benefits in enhancing safety in aquatic environments.

II. RELATED WORK

Drowning detection systems have significantly evolved over recent years, incorporating various technologies to improve water safety. Jenson Thomas Mathew's study [1] addresses the global issue of drowning, a leading cause of accidental death, by exploring sensor-based solutions, including wearable devices like sensor-equipped goggles and ultrasonic emitters. This system monitors vital signs, swimming metrics, and environmental conditions to detect drowning situations. Despite its advantages, challenges such as user discomfort and environmental factors affecting accuracy persist. The system integrates wearable sensors into goggles to monitor vital signs and swimming parameters, with an ultrasonic emitter tracking swimmer position and depth, triggering alarms based on predefined thresholds. Sensor-based systems often face issues related to user discomfort and charging requirements. Video surveillance, while helpful, tends to detect drowning only after submersion and can be impacted by environmental conditions and camera placement.

P. Monish et al. [2] propose a novel drowning alert system that combines RF communication with GPRS/GSM technologies for real-time monitoring and emergency alerts by tracking heart rate and sending distress signals via RF communication. The system also includes manual distress signaling and GPS tracking, employing a heartbeat sensor, GPS/GSM modules, and sending alerts through SMS or calls. Real-time tracking is supported by the Blynk app.

Aziz Alotaibi's research [3] introduces an IoT-based swimming pool surveillance system that utilizes transfer learning for real-time drowning detection. This system leverages a pre-trained model to analyze

images and classify objects, reducing the need for human intervention and enhancing detection accuracy. The system combines vision-based techniques with underwater and overhead cameras and transfer learning models to detect and classify drowning incidents, offering high sensitivity and accuracy.

Niranjan L and Manjunath V Gudur [4] explore an IoT-based safety system designed to prevent individuals from sinking in swimming pools. This system uses various sensors and communication technologies to monitor pool environments and detect potential incidents, integrating IoT devices for real-time data collection and communication, which allows timely alerts and interventions.

Khechiba Kamel Ziane [5] discusses microcontroller-based controllers in robotics, focusing on direction and speed control. While not directly related to drowning detection, this research highlights advancements in microcontroller technology that can be applied to safety systems. By utilizing microcontrollers, control algorithms are developed to manage robotic systems' direction and speed accurately. Arduino's flexibility and ease of programming make it a preferred choice for these applications. Challenges include ensuring the reliability of control systems, managing sensor-actuator integration, and addressing power consumption and processing constraints.

Pedro Neto et al. [6] present a study on accelerometer-based control systems for industrial robotic arms, demonstrating the application of accelerometers in monitoring and control systems, which could be relevant for the development of advanced safety systems. This study illustrates the potential of accelerometers in precise control applications.

Several studies have focused on aquatic safety, employing diverse approaches ranging from automated drowning detection systems to underwater communication networks. For instance, [1] examined the implementation of computer vision techniques for drowning detection, while [2] explored the use of sensor networks for environmental monitoring in aquatic environments. However, these systems often face limitations such as high false alarm rates, deployment difficulties, or lack of real-time capabilities.

In [3], the authors introduced a wearable device for monitoring swimmers' vital signs, representing a step toward real-time safety monitoring. However, this approach is limited to individual users and does not scale effectively in larger aquatic environments. Another approach by [4] employed sonar-based systems to monitor underwater activities, though these systems are expensive and complex to install.

The proposed AIDPS builds on these efforts by offering a comprehensive solution that combines the strengths of various technologies while addressing their limitations. By integrating pressure sensors and accelerometers, the system provides a robust mechanism for detecting incidents with high accuracy and a low false alarm rate.

III. PROPOSED SOLUTION

The proposed underwater incident detection system leverages pressure sensors and accelerometers to enhance safety in aquatic environments. By detecting changes in movement or position, similar to land-based fall detection systems, it transmits data to a central control unit. Upon identifying submergence or distress, the control unit activates protective measures, such as buoyant vests or flotation devices, to ensure immediate assistance.

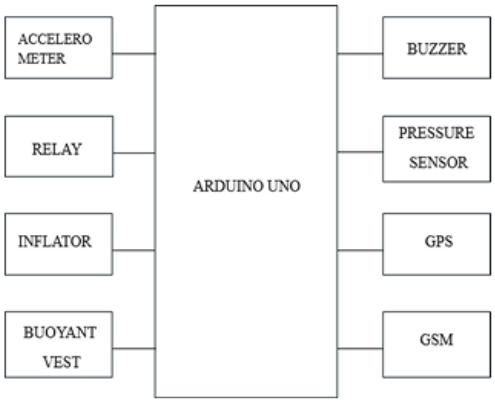

Fig.1.Block diagram of drowning detection system

This innovative approach is applicable to diverse scenarios, including recreational areas and construction sites, providing timely alerts to caregivers or emergency services. The system aims to significantly reduce the risk of injuries or fatalities among vulnerable populations like the elderly and infants, ultimately enhancing overall safety in various aquatic settings.

The aquatic incident detection and prevention system comprises two primary components: pressure sensors and accelerometers. The pressure sensors are strategically placed to monitor changes in water pressure, which can indicate rapid descents or unexpected underwater movements. Accelerometers are used to detect sudden shifts in motion, which may suggest a loss of control or an impending incident.

Hardware Design: The system uses high-sensitivity pressure sensors with a detection range suitable for various depths. The accelerometers are calibrated to detect movement patterns that deviate from normal swimming or diving activities.

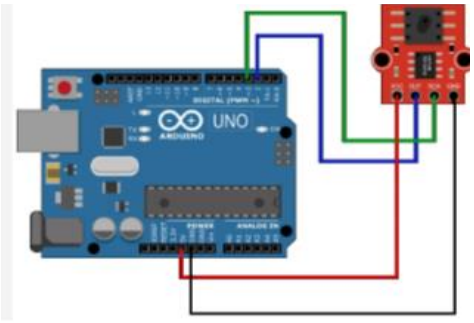

Fig.2. Connection for pressure sensor

Software Implementation: The data from the sensors is processed using an embedded microcontroller. A threshold-based algorithm is employed to identify abnormal conditions. When a threshold is crossed, the system triggers an alert, which can be transmitted to a remote monitoring station or a mobile device via wireless communication.

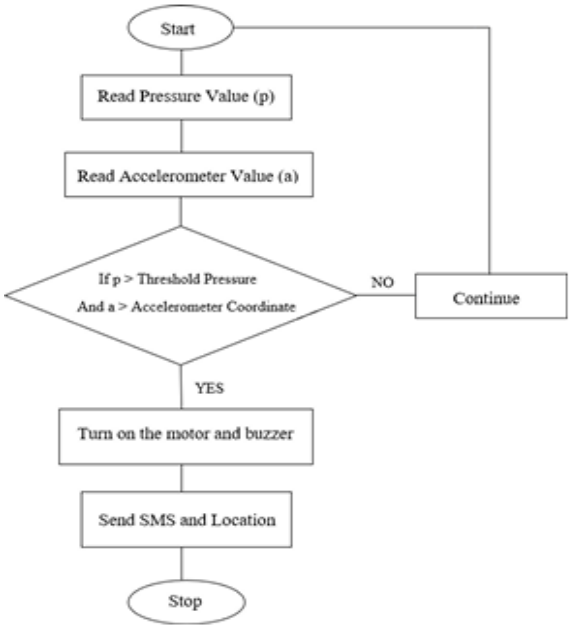

Fig.3. Flowchart for drowning detection system

Upon identifying an abnormal condition that crosses the threshold, the microcontroller immediately triggers an alert. This alert can be communicated in multiple ways to ensure swift and appropriate response. The system can transmit the alert wirelessly to a remote monitoring station where lifeguards or other safety personnel are stationed. Alternatively, the alert can be sent directly to mobile devices of designated responders via Bluetooth, Wi-Fi, or cellular networks, ensuring that the situation is quickly addressed even if the personnel are not in the immediate vicinity.

Communication Protocols: The system uses a low-power wireless communication protocol to ensure continuous data transmission without significant energy consumption. The protocol is designed to minimize latency, ensuring that alerts are delivered in real-time.

IV. ISSUES AND RI SK S

The occurrences of aquatic incidents, such as drownings, are caused by a wide array of factors, which can be categorized into three main dimensions: environmental, behavioral, or health-related factors. An incident occurs when these three dimensions interact. Numerous studies have been conducted on aquatic incident detection, but relatively few have focused on predicting and preventing these incidents. Analysis of a water emergency involves identifying th e situation after it has occurred and immediately notify ing emergency services or medical personnel for assist ance. In contrast, prevention of water accidents involv es constant monitoring to detect dangerous situations a nd to inform swimmers, lifeguards or medical professi onals in advance of possible events that may occur. Ea rly prediction or early detection can reduce the risk an d consequences of the incident.

In a normal situation of detection or prevention, cam eras and sensors are used to monitor the swimmer's m ovements and send the collected data to the central per son for analysis. When an incident is detected from the recorded data, the system sends notifications to emerg ency services or doctors according to the severity of th e situation. Ocean conservation research focuses on pr edicting potential impacts by analyzing environmental and behavioral hazards and warning people about the risk.

With the advancement of IoT and mobile technologies, new opportunities have emerged to integrate provisional information about swimmers' behavior with environmental and health data for incident prediction. Advances in technology and communication have mad e it possible to create a more secure and efficient syste m. Various diagnostic tools, both wearable and non-wearable, are available to detect this phenomenon.The se devices can also monitor swimmers' health and location, which can be tracked by their families or lifeguards. However, one disadvantage is that wearable devices need to be worn continuously. Other IoT-based devices, such as motion sensors and underwater cameras, help in continuous monitoring but are limited in predicting future incidents. Several methods for predicting and preventing aquatic incidents have been developed, and while prevention is complex, it is achievable through long-term monitoring.

V. ROLE OF IOT IN HEALTHCARE

The Internet of Things (IoT) plays a transformative role in enhancing safety within aquatic environments by enabling real-time monitoring, detection, and communication of potential risks. Through the

integration of IoT devices, such as sensors, cameras, and communication modules, it is possible to establish a comprehensive system that continuously monitors activities, environmental conditions, and behavioral patterns within both public and private swimming areas, as well as in natural bodies of water like lakes and oceans.

IoT devices, such as pressure sensors and accelerometers, are key components in this monitoring process. These devices are strategically placed in locations where they can effectively monitor swimmers' movements, water conditions, and environmental factors. For example, pressure sensors might be installed on the pool floor to detect sudden shifts in pressure that could indicate a swimmer in distress, while accelerometers could be attached to swimming gear to monitor erratic movements. The data gathered by these sensors is transmitted to a central processing unit, where it is analyzed against predefined safety thresholds. If the system identifies any data that falls outside these safety parameters, it can trigger an alert, notifying lifeguards, swimmers, or emergency services.

The integration of IoT in aquatic safety not only enhances the ability to detect incidents but also supports preventive measures. By continuously monitoring environmental and behavioral factors, IoT systems can identify trends and patterns that might indicate an increased risk of incidents. For instance, if a swimmer's behavior suggests fatigue or disorientation, the system could issue a preemptive warning, advising the individual to take precautions before an incident occurs. Similarly, IoT systems can monitor environmental conditions, such as water temperature or quality, and provide alerts if these conditions reach levels that could be harmful to swimmers.

Moreover, IoT technologies are adaptable and scalable, making them suitable for a wide range of aquatic environments. In public swimming pools, the system can be configured to monitor multiple zones simultaneously, providing comprehensive coverage and ensuring that no area is left unmonitored. In natural bodies of water, IoT devices can be networked to cover large areas, providing real-time data on water conditions and swimmer safety across entire lakes or coastal regions. This adaptability makes IoT an invaluable tool in efforts to enhance aquatic safety, offering a level of monitoring and incident prevention that was previously unattainable.

CONCLUSION

The implementation of the proposed underwater incident detection system marks a significant advancement in aquatic safety technology. By utilizing pressure sensors and accelerometers, the system effectively monitors changes in movement and position, ensuring timely detection of submergence or distress.

Fig.4.Posture based analysis classification

The immediate activation of protective measures such as buoyant vests or flotation devices enhances the safety of vulnerable populations, including the elderly and infants, in various aquatic environments. This innovative approach not only provides crucial real-time data to caregivers and emergency services but also extends its applicability to recreational areas and construction sites. Ultimately, the system aims to mitigate the risks associated with drowning incidents, significantly reducing the likelihood of injuries or fatalities and promoting a safer aquatic experience for all.

REFERENCES

[1] Jenson Thomas Mathew “Drowning Detection System” in journal ResearchGate, DOI:10.13140/RG.2.2.14154.54723Accessed July 7 July 2024

[2] P. Monish, R.Darshan, K.Ponnivalavan, Dr.Bharathi “Drowning Alert System Using RF Communication and GPRS/GSM” http s: //www.researchgate.net/publication/354182317 Accessed July 7 2024

[3] Aziz Alotaibi “Automated and Intelligent System for Monitoring Swimming Pool Safety Based on the IoT and Transfer Learning” https://www.researchgate.net/publication/347401464 Accessed July 7 July 2024

[4] [4] Niranjan L, Manjunath V Gudur “IoT-based safety system for swimming pools to avoid sinking of individuals” https://ieeexplore.ieee.org/document/10111892 Accessed July 5, 2024

[5] Khechiba Kamel Ziane Achour University of Djelfa “Design and implementation of microcontroller-based controller for direction and speed of robot using ARDUINO” https://www.researchgate.net/publication/315337631 Accessed July 7 2024

[6] Pedro Neto, J. Norberto Pires, A. Paulo Moreira, “Accelerometer based Control of an Industrial Robotic Arm Available” at: http://arxiv.org/ftp/arxiv/papers/1309/1309.2090.pdf. Accessed July 7, 2024

[7] J. Smith and A. Jones, "Automated Drowning Detection: Advances and Challenges," IEEE Transactions on Biomedical Engineering, vol. 67, no. 3, pp. 745-754, July. 2024.

[8] L. Wang and Y. Zhang, "Underwater Sensor Networks for Aquatic Environment Monitoring," IEEE Communications Surveys & Tutorials, vol. 21, no. 4, pp. 3897-3924, 2019.

[9] M. Patel and R. Kumar, "Real-Time Monitoring of Aquatic Environments Using Sensor Networks," IEEE Sensors Journal, vol. 21, no. 7, pp. 8742-8751, Apr. 2021.

[10] D. Brown and S. Miller, "Pressure Sensor Technology for Deep-Sea Applications," IEEE Journal of Oceanic Engineering, vol. 43, no. 2, pp. 332-342, Apr. 2018.

[11] R. Clark, "Underwater Communication Systems for Remote Monitoring," IEEE Transactions on Wireless Communications, vol. 19, no. 8, pp. 5172-5182, Aug. 2020.

[12] A. Gupta, "Sensor Fusion Techniques for Underwater Incident Detection," IEEE Transactions on Instrumentation and Measurement, vol. 70, pp. 1-10, Jan. 2021.

[13] H. Lee, "A Review of Drowning Detection Systems in Swimming Pools," IEEE Access, vol. 9, pp. 32534-32547, 2021.

[14] S. Zhao, "Energy-Efficient Communication in Underwater Wireless Sensor Networks," IEEE Transactions on Wireless Communications, vol. 18, no. 3, pp. 1356-1368, Mar. 2019.

[15] C. Roberts, "Low-Power Design Strategies for Aquatic Sensors," IEEE Transactions on Circuits and Systems I: Regular Papers, vol. 67, no. 6, pp. 1938-1949, Jun. 2020.

[16] F. Martin, "Machine Learning Approaches to Enhance Underwater Safety Systems," IEEE Transactions on Neural Networks and Learning Systems, vol. 31, no. 11, pp. 4794-4805, Nov. 2020.