

Smart Water Safety for Children: IoT-based Monitoring and Emergency Alert System

Irda Roslan¹, Wong Joe Xien¹, Ariff Idris¹, Khadijah Wan Mohd Ghazali¹, Mohd Faez Alwi²

¹Faculty Technology Maklumat dan Komunikasi, University Technical Malaysia Melaka, Malacca, Malaysia

²CTRM Aero Composites, Malacca, Malaysia

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ABSTRACT

Drowning is a leading cause of accidental deaths among children, largely due to insufficient supervision and delayed emergency responses. This paper presents the development of the Smart Water Safety for Children system, an Internet of Things (IoT)-based prototype designed to enhance child safety during aquatic activities. The proposed system integrates multiple sensors including a MAX30100 pulse oximeter, a water-level sensor, and a NEO-6MV2 GPS module, all managed by a NodeMCU V3 microcontroller. These components collect real-time physiological and positional data from the child, which is transmitted via Wi-Fi to a Firebase cloud database and visualized through a mobile application developed on Android Studio. The application provides guardians with real-time updates on heart rate, oxygen saturation, and location, issuing alerts when critical thresholds are detected. Functional and physiological testing confirms the system's reliability in identifying near-drowning scenarios and effectively notifying emergency contacts. This system demonstrates a cost-effective, scalable, and accessible solution for enhancing aquatic safety among children.

Keywords- IoT, near-drowning detection, real-time monitoring, emergency alert, child safety

INTRODUCTION

Drowning ranks among the top ten causes of accidental deaths worldwide, with an estimated 372,000 fatalities occurring annually. According to the "National Drowning Report" by Royal Life Saving Australia, drowning incidents rose by 20% between 2020 and 2021. Several factors contribute to drowning, such as pre-existing medical conditions like heart issues, substance abuse, and lack of swimming skills. Additionally, the primary cause of drowning-related deaths in children is insufficient supervision. The 2014 Global Report on Drowning highlights that children aged 1–4 years are at the highest risk due to lack of adult oversight, followed by those aged 5–9 years [1].

In general, there are five distinct phases in drowning. The initial phase includes a brief attempt to catch one's breath, followed by the second phase, where the individual holds their breath to prevent water from entering the lungs. Near-drowning incidents typically occur during the first and second phases. During these stages, blood oxygen saturation decreases, while the heart rate accelerates to compensate for oxygen delivery disruptions and ensure the body receives adequate oxygen. Factors such as heart attacks, loss of consciousness, or head and spinal injuries can prevent a diver from resurfacing. A reduced oxygen level in the blood (hypoxemia) is a common feature of all near-drowning cases. As drowning progresses, the larynx (air passage) involuntarily closes to block air and water from entering the lungs [2]. The third phase begins when the individual stops breathing and becomes unconscious. To prevent this progression, drowning must be detected no later than the third phase [3]. Preventative measures include close supervision, swimming training, and teaching basic swimming rules and etiquette. While these strategies have been effective to some extent, they are not foolproof.

Near-drowning alert systems are classified into two types: image processing systems and IoT sensor-based systems. Image processing systems use algorithms to analyze live video footage for signs of drowning [1]. These

systems often require the use of drones to cover large areas, leading to safety concerns and practical challenges such as limited drone battery life. While image processing methods outperform sensor-based systems in terms of accuracy, they are less effective in situations where drowning occurs in murky water, making swimmers difficult to detect. IoT sensor-based systems, on the other hand, rely on devices like oximeters and water-level sensors to monitor user conditions. Various drowning detection methods were analyzed based on their accuracy, complexity, and cost. Sensor-based devices are generally classified as having low to moderate complexity and cost, whereas image processing systems are regarded as more complex and expensive [1]. Thus, efforts to develop sensory systems in the form of wearable devices for drowning detection are increasingly prevalent.

The objective of this system is to facilitate the rapid rescue of individuals experiencing near-drowning incidents. It serves as a monitoring system that tracks the user's heart rate and oxygen levels, making it particularly suitable for parents to supervise their children while swimming. The system is designed to detect irregularities in heart rate or oxygen levels and provide a drowning alert, including the user's location. The sensors are connected to a NodeMCU (ESP8266) microcontroller. Equipped with a Wi-Fi module, the ESP8266 enables notifications to be sent directly to Android apps on users' smartphones.

Related Works

The integration of Internet of Things (IoT) technologies in drowning detection systems has garnered significant attention in recent years. Researchers have developed various prototypes aimed at improving child safety in aquatic environments by enabling real-time health monitoring and emergency alert capabilities. These systems generally share core attributes such as network connectivity, mobile application integration, cloud-based data storage, and the ability to process physiological data like heart rate, oxygen saturation, and movement. The primary goal is to ensure rapid detection and intervention in near-drowning incidents, particularly among children.

Ramdhan et al. [4] developed an EDDS system designed to alert parents and lifeguards when an abnormal heartbeat is detected. The system employs Radio Frequency (RF) as the communication protocol between the transmitter and receiver. A PPG sensor is used to monitor heart rhythm by utilizing a light source to measure the heartbeat. The system incorporates an Arduino Pro Mini 328 (433MHz UART) microcontroller to process the signals from the pulse sensor and transmit them to an access point (Raspberry Pi2). The access point, connected to the internet, forwards the data to a database. Once an abnormality is detected, a warning signal is sent to guardians via a webpage or Android app. The monitoring web page and smartphone app are updated every second, enabling parents and lifeguards to continuously track the swimmer's status. The monitoring web page displays essential information such as time, BPM values, and the swimmer's current condition.

Farid et al. [5] developed a child drowning alert system using an IoT PPG sensor to assist parents in monitoring their children in the pool. The system includes a heart rate sensor and a NodeMCU microcontroller. The heart rate sensor monitors the children's heart rate, while the NodeMCU runs an algorithm to differentiate between normal and drowning heart rates. The system connects to a smartphone via Wi-Fi using the Blynk application. If the detected heart rate exceeds the preset threshold, the microcontroller sends a warning notification to the parents.

Monish et al. [6] developed a drowning alarm system utilizing RF transmission and a GPRS/GSM module. The proposed system consists of three main components. The first component is the RF transmitter and receiver, managed by an ATmega328 microcontroller from the AVR family, which is connected to an LCD screen and powered by a 12V battery. The heart rate of the individual in the water is displayed on this LCD screen. The receiver circuit, similar in design, uses an AVR microcontroller and an RF module powered by a 12V transformer. In an emergency, when the individual's heart rate becomes critical, a distress signal is sent to the receiver circuit, activating an LED and buzzer. A GPS module pinpoints the individual's location and transmits it to the Blynk server via GSM, where it is displayed on the Blynk application. This allows lifeguards to perform live tracking of the person in the water and identify their location using the Blynk app on a smartphone.

In another study, Purnomo et al. [7] developed a wearable health monitoring device using the MAX30100 sensor, capable of tracking heart rate and SpO₂ levels in real-time. It was integrated with an Android application using Firebase as cloud storage, enhancing accessibility and data logging. Although not specific to drowning, the

technology has similar applications in water safety systems. Meanwhile, Khan et al. [8] proposed an IoT-based child safety wearable with multi-sensor input, including GPS and environmental data. The system emphasizes child location tracking and alerts in critical situations, with potential adaptation for aquatic environments. Their work underlines the growing trend of merging GPS, GSM, and health monitoring into compact wearable platforms. A study by Ramesh et al. [9] implemented a smart life-saving jacket designed for swimmers, which incorporates heart rate sensors, accelerometers, and GSM modules. When critical heart activity or sudden motion is detected, the system automatically inflates an airbag and sends emergency alerts. Such systems emphasize how wearable IoT can transition from passive monitoring to active intervention.

Collectively, these studies showcase the rapid progress of IoT in health and safety monitoring applications. While earlier systems relied on GSM and RF communication, more recent designs now leverage real-time cloud services like Firebase and advanced mobile app platforms for better scalability, user experience, and cross-platform functionality. These advancements contribute to the continuous improvement of drowning detection systems tailored for children, improving parental response time and overall safety.

METHODOLOGY

The Smart Water Safety for Children System aims to help parents keep track of their children's swimming safety by monitoring their heart rate and oxygen saturation levels. It also records the child's location when a near drowning incident is detected. The system's primary objective is to enable timely rescue by sending SMS alert notifications to parents. The system includes three sensors connected to a NodeMCU V3 microcontroller: a water-level sensor, a heart rate and pulse oximeter sensor (MAX30100), and a GPS sensor (GPS neo-6mv2). The MAX30100 sensor integrates pulse oximetry and heart rate monitoring capabilities, combining two LEDs, a photodetector, optimized optics, and low-noise signal processing to capture heart rate and oxygen-level signals accurately.

A child is considered to be in a near-drowning state when their oxygen saturation drops below 95%, their heart rate exceeds 140 BPM, or other irregular heart rhythms are detected [10]. The system leverages a Wi-Fi module to facilitate communication. When such critical conditions are identified, an alert notification containing the child's current location is sent to the parents.

The NodeMCU V3 microcontroller gathers data from the sensors and transmits it to Firebase cloud storage. Parents can access and monitor real-time heart rate and oxygen saturation levels through an Android-based mobile application. This app, developed as part of the Smart Water Safety for Children system, is tailored to control and monitor the system's hardware. It provides a user-friendly interface, enabling parents to view their child's vital signs directly from their smartphone.

Project Methodology

Figure 1 depicts the Prototype Model as the methodology used to develop the system. The methodology comprises six stages: Requirement Gathering, Quick Design, Prototype Development, User Evaluation, Prototype Refinement, and Product Engineering.

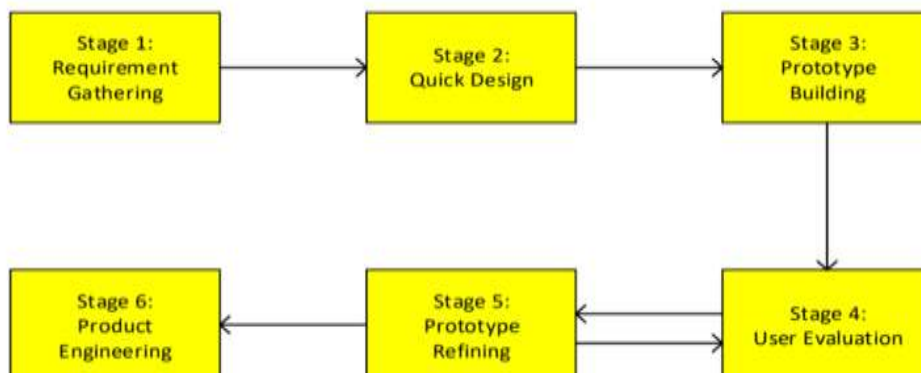


Figure 1. Prototype Model

In this system, the requirements specify that the prototype must include basic sensor functionalities to monitor metrics such as heart rate, oxygen levels, and location. Consequently, the tool should incorporate these sensors and provide the capability to view the results through an accompanying mobile application. Table 1 shows the hardware and software requirement for this system.

Table 1 Hardware And Software REQUIREMENTS

Component	Description
NodeMCU V3	A microcontroller development board with Wi-Fi capability. It uses an ESP8266 microcontroller chip
MAX30100	An integrated pulse oximetry and heart rate monitor sensor
Jumper Wire	Connect breadboard components to the microcontroller and sensors
GY-NEO6MV2	A low-cost yet powerful GPS receiver
Water-level sensor	A cost-effective high-level/drop recognition sensor is achieved by using a series of parallel exposed wire traces that measure water droplets or volume to determine the water level.
Arduino IDE	An open-source application compiler to run code on microcontroller
Android Studio	A platform for easily creating interfaces for managing and monitoring hardware projects from Android mobile.
Fritzing	An open-source hardware initiative that makes electronics accessible

In the quick design stage, the essential functions, mobile application interface design, input and output, and usage flow are all included. This can be done by using Fritzing that incorporates data gathered in earlier stage. Next, an initial version of the prototype was constructed to showcase the system's functional model. During this phase, the circuits and components were assembled and tested. Programming was developed simultaneously, as coding is crucial for enabling the components to operate. Once the device is functional, additional coding is required to ensure the Android mobile application operates effectively.

The completed prototype was tested and reviewed by users, making this stage essential for evaluating the system's strengths and weaknesses. Valuable feedback was gathered from users, enabling improvements to the system. During this phase, the mobile application's user interface, design, and functionality were also assessed. Based on user feedback and requirements, the prototype will be updated with new features and adjustments during the prototype refining stage. This iterative process will continue until users are satisfied with the prototype. The refined prototype will then be used as a foundation to develop the final system, with enhancements made until the final product is complete.

Once all necessary procedures and approvals are completed, the prototype entered its final development phase. During this stage, the technology was fine-tuned and integrated into the final product. The completed version was then undergoing thorough testing to ensure proper functionality and error-free performance. Ongoing maintenance will be required to address bugs, manage updates, and deploy new software versions as needed.

Project Design

The architectural framework of the Smart Water Safety for Children System, as illustrated in Figure 2, presents an integrated IoT-based solution aimed at enhancing child safety during swimming activities. At the center of the system is the NodeMCU V3 microcontroller, which acts as the main processing unit responsible for collecting, processing, and transmitting data from multiple connected sensors.

The system incorporates three primary sensors. The MAX30100 pulse oximeter monitors the child's heart rate and blood oxygen saturation (SpO₂), both of which are essential indicators of physiological health. If the heart

rate rises above normal or oxygen levels fall below a safe threshold, the system recognizes this as a possible near-drowning situation. To determine whether the child is submerged, a water-level sensor is used. This sensor detects when water levels surpass a predefined value, confirming that the child is in a swimming or underwater environment.

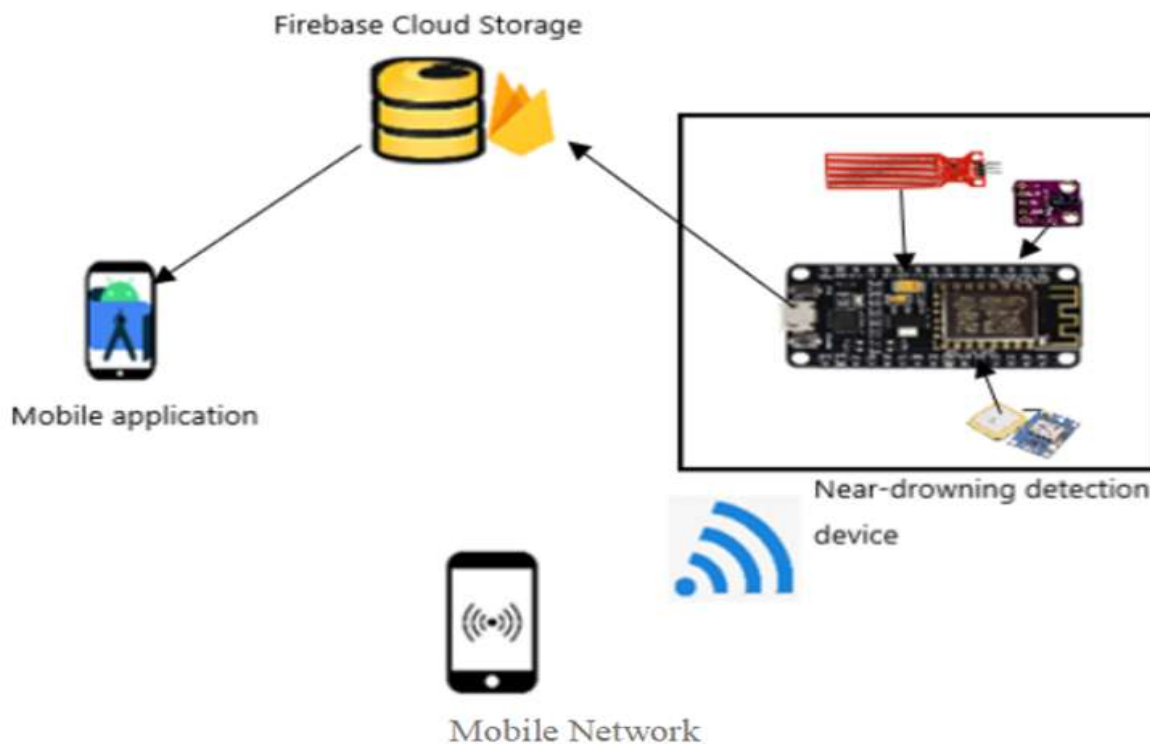


Figure 2. System Architecture

This helps in assessing the child's condition in real-time. Additionally, a NEO-6MV2 GPS module is integrated to provide accurate location tracking. This feature is vital for emergencies, allowing caregivers or emergency responders to locate the child promptly.

The data collected from all sensors is transmitted over a Wi-Fi connection, using the ESP8266 module within the NodeMCU, to a Firebase cloud server. A mobile application developed on the Android platform then retrieves this data and presents it in an easy-to-understand interface. Parents can monitor real-time updates on their child's heart rate, oxygen levels, submersion status, and location, enabling swift and informed responses in critical situations. A key feature of the system is its ability to send automated notification alerts when signs of near drowning are detected, allowing guardians or emergency responders to act promptly. This provides a practical and reliable method to improve water safety for children.

Figure 3 presents the physical prototype configuration of the Smart Water Safety for Children System. The setup includes the NodeMCU V3 microcontroller, LED indicators, a buzzer for local alerts, and the sensors—MAX30100 pulse oximeter, NEO-6MV2 GPS sensor, and a water-level sensor. This integrated design facilitates both immediate local warnings and remote alerts, enhancing the overall responsiveness and reliability of the system in emergency situations.

The operational flow of the proposed system begins with the user launching the dedicated mobile application on an Android smartphone. Upon initialization, the application establishes a connection with the prototype hardware via a shared local Wi-Fi network, ensuring real-time communication between the device and the phone. The prototype, which is equipped with various sensors, then actively monitors the user's vital signs, specifically heart rate and blood oxygen saturation (SpO₂). These physiological readings are captured and transmitted wirelessly to the Firebase cloud server, acting as the centralized data repository.

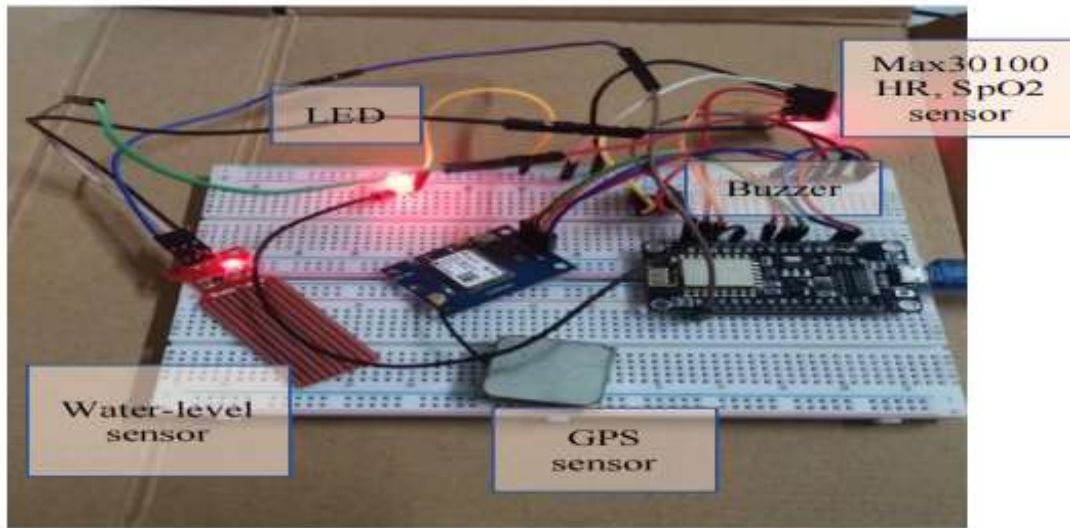


Figure 3. Prototype setup

Once the data is stored in Firebase, the mobile application retrieves it and presents the readings through a user-friendly interface, allowing real-time monitoring on the smartphone. The system is designed to detect signs of potential danger while the user is in the water. If the water-level sensor detects a value above 400, it indicates that the user is likely swimming or submerged. During this condition, the system continuously monitors the user's vital signs. If the heart rate exceeds 140 beats per minute (BPM) and the SpO₂ level drops below 95%, the system interprets these signals as symptoms of potential distress or near-drowning.

In response, an automatic alert notification is generated and sent directly to the user's registered emergency contact, such as a parent or guardian. This alert includes critical information such as the user's current health status and their real-time GPS location, enabling immediate intervention. This process ensures prompt awareness and response during emergencies, potentially preventing fatal outcomes due to drowning incidents.

The user interface of the Smart Water Safety for Children System application is designed with two main functional fragments to provide comprehensive monitoring and quick access to critical information. Figure 4 illustrates the visual layout and design of this application interface, where Status Fragment and Location Fragment can be found. These fragments are structured to enhance user experience and facilitate real-time tracking of the child's safety status while swimming.

The Status Fragment serves as the primary dashboard for monitoring the child's physiological data. It displays vital health indicators such as heart rate and blood oxygen saturation (SpO₂) levels. This real-time data is presented in an intuitive format, allowing parents or guardians to continuously observe the swimmer's condition. The interface is designed to highlight abnormal readings—for example, elevated heart rate or reduced oxygen levels—ensuring that any sign of distress is immediately noticeable. Additionally, the swimmer's overall status, whether in a normal or near-drowning condition, is also indicated clearly in this fragment.

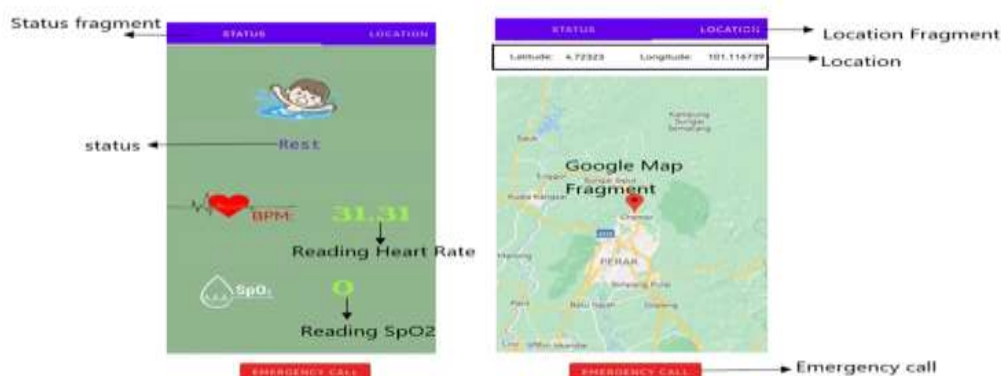


Figure 4. Interface Design

The Location Fragment, on the other hand, provides geographic tracking capabilities. It features a dynamic map that displays the swimmer's current position, enabling users to visually locate the child in real time. The interface also provides precise latitude and longitude coordinates, ensuring accurate location information is available, which is crucial in emergencies. This geolocation data is updated continuously as long as the system remains active and connected to the network.

Together, these two fragments offer a comprehensive monitoring solution by integrating both health data and location tracking.

FINDINGS & ANALYSIS

This section presents the experimental findings derived from the development and validation of the Smart Water Safety for Children System prototype. The analysis is structured into two key components: system functionality testing and physiological data analysis under simulated near-drowning conditions. The primary aim is to evaluate the system's effectiveness in real-time monitoring, accurate data acquisition, and timely notification under critical conditions.

Functionality Testing

To validate the operational reliability of the Smart Water Safety for Children system, a comprehensive functionality test was conducted. The primary objective was to assess whether each subsystem including hardware integration, software communication, and user interface responsiveness met the design specifications for a real-time, IoT-based drowning alert solution.

The testing procedure encompassed individual and integrated component evaluations under simulated conditions. Each test case focused on a specific system function, with predefined performance benchmarks. These benchmarks were determined based on the system's core requirements: real-time physiological data monitoring, wireless transmission, user alert activation, and emergency communication. The key functionalities tested included:

1. **Wireless Network Connectivity:** Establishing a stable and consistent connection between the prototype and local Wi-Fi for uninterrupted data flow.
2. **Sensor Input Validation:** Ensuring accurate and continuous measurement of heart rate (BPM), blood oxygen saturation (SpO₂), and water-level detection.
3. **Cloud Synchronization:** Verifying real-time data transmission and storage in the Firebase cloud database using the ESP8266 Wi-Fi module.
4. **Mobile Application Display:** Confirming accurate rendering of physiological data on the Android interface, synchronized with the cloud.
5. **Emergency Alert Activation:** Testing the system's automated response when physiological thresholds (BPM > 140, SpO₂ < 95) are crossed, triggering buzzer, LED, and push notifications.
6. **Location Tracking:** Assessing the real-time retrieval and display of GPS coordinates within the mobile application.
7. **Emergency Call Feature:** Validating the function that allows users to directly initiate a call to emergency services through the application interface.

The outcomes of the functionality testing are detailed in Table 2. All functional components demonstrated expected behavior, passing the evaluation criteria. These results confirm the prototype's capability to perform consistently under simulated near-drowning conditions and affirm its potential for real-world deployment.

Table 2 Functionality Testing Result

Test ID	Function Evaluated	Expected Outcome	Observed Outcome	Status
1	Wi-Fi Connectivity	Stable connection with local network	Successfully established	Pass

2	Sensor Input (Pulse, SpO ₂ , Water Level)	Continuous and accurate acquisition	Real-time values detected and logged	Pass
3	Firebase Cloud Sync	Data transmitted and stored in cloud	Real-time synchronization achieved	Pass
4	Android Application Display	Correct display of live data	Interface responsive and accurate	Pass
5	Emergency Alert Trigger	Alert generated when BPM > 140, SpO ₂ < 95	Alerts activated (LED, buzzer, notification)	Pass
6	GPS Location Retrieval	Accurate geographical location on mobile app	Real-time coordinates displayed	Pass
7	Emergency Call Function	Initiate direct call to emergency services	Call triggered successfully	Pass

Physiological Data Analysis

Following system validation, controlled testing was conducted to simulate physical exertion and submersion, replicating conditions associated with near-drowning. The test subject performed light swimming and cardio exercises while wearing the prototype. Sensor readings were continuously logged and transmitted for analysis.

Key physiological metrics monitored included heart rate (BPM), SpO₂ levels, and water-level sensor values. The system is designed to trigger an alert when the heart rate exceeds 140 BPM and oxygen saturation drops below 95%, provided the water-level sensor value is above 400, indicating submersion.

To evaluate the functionality and reliability of the Smart Water Safety for Children System, a series of repeated measurement trials were conducted under controlled scenarios (Table 3 until Table 6). These tests aimed to validate whether the sensor-based thresholds accurately detected near-drowning conditions while minimizing false positives. Data were collected across four experimental conditions: resting state, swimming without exertion, exercise without swimming, and a combination of swimming with exercise. Each scenario was repeated five times to ensure consistency, with pulse rate (BPM), oxygen saturation (SpO₂), and water level serving as the core indicators. The yellow highlights in the tables indicate instances where near-drowning was detected, based on the criteria of water level exceeding 400, heart rate surpassing 140 BPM, and oxygen saturation dropping below 95%.

Table 3 Resting State (No Exercise/Swimming)

Test Data	1	2	3	4	5
Water-Level	80	67	70	69	74
Heart Rate (bpm)	83.8	79.5	84.2	89.7	70.8
Oxygen-Level (%)	98	98	98	97	98

Table 4 Swimming Only Condition

Test Data	1	2	3	4	5
Water-Level	562	555	544	533	526

Heart Rate (bpm)	89.5	90.2	87.9	78.3	100.4
Oxygen-Level (%)	98	98	98	97	97

Table 5 Exercise Only Condition

Test Data	1	2	3	4	5
Water-Level	56	64	52	58	55
Heart Rate (bpm)	110.5	120.3	135.4	140.5	139.7
Oxygen-Level (%)	96	94	95	95	94

Table 6 Exercise And Swimming Condition

Test Data	1	2	3	4	5
Water-Level	513	512	509	507	508
Heart Rate (bpm)	103.3	110.8	132.5	144.8	147.8
Oxygen-Level (%)	95	94	95	94	94

In the first scenario, the data for resting condition without swimming or physical exertion is gathered as shown in Table 3. The water-level sensor consistently registered values below 100, confirming that the subject was not submerged. The heart rate ranged from 70.8 to 89.7 BPM, with SpO₂ readings holding steady at 98%. These values fall well within normal physiological ranges for a resting individual and serve as a control reference for other test scenarios. The absence of alerts during this state confirms that the system does not falsely trigger under normal, non-risk conditions.

Table 4 represents the second scenario where data for swimming without exercise is collected. In all the test cases, the water level exceeded 400, indicating active submersion. Despite this, heart rate values remained below 100 BPM and SpO₂ levels maintained at 97–98%, suggesting that submersion alone does not induce a critical health event. Importantly, the system correctly refrained from sending any alert notifications, validating that the presence of water alone is not a sufficient trigger unless accompanied by abnormal physiological signals.

The third scenario involved exercise without submersion as shown in Table 5. The water level values remained below 100, while the heart rate increased significantly—ranging from 110.4 to 140.5 BPM—due to physical exertion. Oxygen saturation slightly decreased to 94–95%, reflecting increased metabolic activity. While these readings suggest physiological stress, the system did not send alerts, as the water-level threshold indicating submersion was not breached. This confirms that elevated BPM or minor reductions in SpO₂ alone are insufficient to activate the alert system.

The fourth and most critical scenario which combined swimming with physical exertion as displayed in Table 6, emulating a near-drowning event. In this condition, both heart rate and SpO₂ parameters crossed the system's predefined critical thresholds. Heart rate exceeded 140 BPM in two out of five trials, and SpO₂ levels dropped below 95%, with water levels consistently above 400. Under these conditions, the system successfully triggered

alert notifications, including real-time location tracking, verifying that the logic for detecting near-drowning scenarios is operational and precise.

Overall, the findings confirm that the system reliably distinguishes between non-critical and critical states by assessing a combination of water submersion, elevated heart rate, and reduced oxygen saturation. The multi-sensor approach ensures contextual awareness, reducing false positives while enabling timely emergency alerts when actual risk is present. The consistency and accuracy of the results across all test repetitions underscore the robustness of the system and its practical applicability in real-time drowning prevention for children.

The analysis confirms that the Smart Water Safety for Children System prototype is capable of real-time monitoring and accurate detection of potential near-drowning conditions based on predefined thresholds. The integration of the MAX30100 pulse oximeter, GPS module, and water-level sensor, combined with cloud-based synchronization via Firebase, allowed for timely and efficient alert delivery. The mobile application interface, developed using Android Studio, demonstrated seamless data retrieval and visualization, enhancing user accessibility and situational awareness.

While the system performed as intended under test conditions, certain limitations were noted. Environmental factors such as water splashes, sensor misalignment, and fluctuating ambient light may affect optical sensor reliability. In future iterations, enhancements such as sensor fusion algorithms and waterproof casing are recommended to further improve accuracy and robustness.

CONCLUSION

The Smart Water Safety for Children System presents an innovative solution to support parents in actively monitoring their children's swimming activities and preventing near-drowning incidents. By integrating real-time health tracking and geolocation features into a user-friendly Android application, the system enables immediate alerts and emergency responses when critical conditions are detected. The application not only displays the child's heart rate and oxygen saturation but also pinpoints their exact location during distress, allowing parents to act quickly. If the child is out of visual or physical reach, the built-in emergency call function offers a direct link to emergency services, ensuring swift intervention.

The system is specifically designed for children aged 2 to 12 years old, addressing a highly vulnerable age group. While the prototype has demonstrated its potential in detecting life-threatening scenarios and facilitating early rescue responses, its current form still has room for improvement. One limitation is the hardware's vulnerability to water exposure. Future development should focus on creating a fully waterproof version of the device to ensure functionality in real-world aquatic environments. Additionally, incorporating more sensors such as accelerometers to detect sudden movements or stillness, and temperature sensors to monitor changes in the child's body or environment, could greatly enhance the reliability of the detection system. Another proposed improvement is the integration of a child-friendly airbag mechanism, which could help keep the child afloat during emergencies, increasing the likelihood of survival before rescue personnel arrive.

In conclusion, the system demonstrates a promising approach to child water safety by leveraging IoT technologies, and future enhancements could make it a critical tool in drowning prevention and emergency preparedness.

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