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INTELLIGENT UNDERWATER SYSTEM FOR HEALTH MONITORING AND COMMUNICATION TO ENHANCE MARINE WORKER SAFETY AND PERFORMANCE

Abini M.A.[1]

[1]Assistant Professor, Department Of ECE, KMEA Engineering College, Kerala, India.

ABSTRACT

Underwater communication encompasses the trans- mission of data using various methods including acoustic waves, radio frequency signals and optical communication technologies. These systems are crucial especially for the underwater sensing and navigation needs and other marine activities, wherein underwater wireless optical communication may be regarded as one of the most prominent features due its high rate of data transfer but also over long distances. Today many Marine workers work in dangerous environments such as in very deep seas, at low temperatures and even in poisonous surroundings, therefore monitoring health status is one of the core components concerning safety and operational end efficiency. The particular paper describes the Smart Underwater System designed to observe the health status of marine workers in synchronous mode. Underwater communication systems are crucial due to the long distances involved in the transfer and reception of signals. Such critical signs of life as heart rate and body temperature measured using wearable sensors are forwarded through a wireless communication network to a surface monitoring station. The goal of this system is to improve safety measures of offshore oil production and reduce occupational health incidence rates by offering the chances of receiving prompt treatment thus ensuring the safety of workers and efficiency of operations and their productivity.

Keywords: Underwater Communication, Health Monitoring, Wireless Sensors, Marine Safety, Real-Time Data Transmission, Wearable Technology.

1. INTRODUCTION

Marine workers work under extremely tough conditions, risking their lives, as they often perform underwater construction, maintenance and inspection work [1]. These jobs require them to work at great ocean depths, endure intense temperatures, and possibly deal with hazardous chemicals. Hence, their health and life are in jeopardy and they become susceptible to numerous health conditions like frostbite, pressure-related ailments and chronic diseases due to extreme conditions. These days, as the marine sector is becoming more popular it is more important than ever to ensure the safety of marine worker for both their health and for efficiency of operations. Health Monitoring Systems in marine environments are new. For underwater health monitoring systems, underwater working environments are indeed unique and therefore they require innovative approaches. Moreover, it has been pointed out that traditional safety measures rely on aspects such as routine inspections while others rely on mere observation. However, it is clear that medical assistance is not immediate due to the remoteness of underwater tasks or engagements. In this regard, [2] there exists a gap to be filled in form of an appropriate health monitoring system that is able to perform real- time monitoring and allow quick response actions to medical triggers. Recent developments in technology have made it easier to create wearable sensors that are capable of tracking heartbeat, oxygen saturation and body temperature. These sensors have been effective for use on land, however, their application in underwater areas has not been widespread owing to water pressure, extremes of temperature, and difficulties in transmitting data.

In this paper, a Smart Underwater System for construction in particular is presented which combines advanced sensor technology with wireless communication in order to solve these problems thereby ensuring that marine workers can be continuously monitored. The system that is proposed relies on health sensors that can be worn by the workers and with the data of certain physiological parameters being collected without any wires and sent to a monitoring station. These diffusion of real time data allows for a feedback to be given concerning the health of the worker before health issues arise, thus mitigating health complications. As an example, a sharp drop in the blood oxygen level of an employee is problematic since this can be the sign of breathing issues or certain malfunctioning of the device, which he is operating at the time. Surface personnel in this instance should show up at once. The monitoring system [3] along with the surface monitoring base can track the well being of individuals by sending notifications to the supervisors and medical teams when the notice conditions go beyond the normal vital sign range. The prevention is the means to use in advance which not only can provide the safety of employees in the process but it is also capable of minimizing the serious complications of health as it can provide the quick reaction at the initial stages. In this way marine organizations will be able to create a culture of safety, streamline the performance of the organization and consequently enhance job satisfaction. The use of high-tech health monitoring solutions will be inevitable to address the emergent challenges and be of high safety standards because the maritime industry is a constantly evolving sector. Most importantly, marine employees should be checked using technologies that are capable of detecting health problems among them. The Smart Underwater System is a significant innovation in terms of safety, which is based on real-time monitoring to reduce the risks associated with underwater activities. This system is a great relief to the marine workers, since the health and safety protocols are enhanced, thereby making their tasks easier and quick.

2. LITERATURE REVIEW

For remote diver health monitoring, C.V. Vivekanand, et al. (2023) [4], affirm the recommendation of a method employing underwater sound communication. The vital signs are their sensors that track them, which through the LCD screen are displayed. A GPS-enabled SOS message is sent in case of an emergency occurring. Due to this technology, real time health monitoring and prompt emergency interventions become feasible. Remote monitoring which is situated deep in the sea of diver's health system is given in the research of K U Menon et al. (2014) [5]. The data is merely transmitted when the problems are diagnosed. Regardless of sending only the fundamental health data to the system, the system is LabVIEW secured and the acoustic test bed systems ensure that it is robust and accurate in the health control of the people in diving operations.

Gunanandhini et al., (2023) [6] in their research detail a system to monitor real-time health during scuba diving that transmits crucial health data through the underwater wireless mode. It is because of the technology that the continuous monitoring and quick responses to the health threats are possible, and it also accentuates the difficulties in underwater communication reproduction in the lab settings. Netchaev and other authors (2016) [7] describe the innovative underwater SDR system that communicates through electromagnetic waves for wireless telemetry in areas that are hard to reach, in contrast to the limitations of acoustic communication. On the basis of the successful operation in the last year, the project meets its milestones with a minimum delay. SDR is an elaborated, easily installed and removed, and it allows long and medium-range underwater communication technology. High-speed optical communication [8] has significant ad- vantages over acoustic techniques. It is associated with the following benefits: less latency, less noise, and more data rates (1–10 Mbps). This is proven by the tests held at 100–200 meters, namely for data retrieval and vehicle control in an environment with less noise.

The research paper by HG Rao et al., 2016 [9] published delves into the question of underwater laser communication using PMTs with low signals, and using APDs with high signals. Their study demonstrated communication that is re-liable even under severe circumstances, dealt with the issue in Narragansett Bay, and was able to reach 8.68 Mb/s speeds by using error-free transmissions with distances from 22.4 to extinction times. L. Zhang et al. (2018) [10] put forward a modified m-QAM- OFDM technology for enhancing UWOC, which could be used to advance BER performance and the triggering of underwater messages in both clear and turbid waters on the sea. Li-Fi is investigated by R. Latha et al. (2024) [11] for environmental alerts and underwater health monitoring, improving diver safety with quick, secure communication despite line-of- sight restrictions.

As a means to quick emergency reaction with IoT, KR Prabha et al. (2023) [12] recommend monitoring of pulses, which will activate an airbag and rescue a diver with constrictions of blood vessels. This approach uses a Raspberry Pi 3B+ to deal with such a situation. Elsewhere, the expensive and dangerous challenges of tidal energy systems have been attracting attention. The tool for the detection of underwater cable damage, which is discussed in the article by Sudheer and TIP consortium (2017) a [13] and deals with the case of the Indian Ocean, is developed.

K. Karthikeyan et al. (2023) [14] discuss the underwater health monitoring using Li-Fi by tracking vital signs and transmitting data only when critical events occur to conserve energy. Li-Fi is still facing issues like signal attenuation, but it can be considered safer and more economical for real-time monitoring. A.B. Noel et al. (2017) [15] evaluates the structural health monitoring of vital infrastructure using WSNs, focusing on sensors for detecting stress and deformation. In demonstrating how WSNs improve safety and monitoring, the study points out scalability and energy issues. D. Stramsk et al. (2001) [16] present a model that examines 18 planktonic components; it shows that bacteria dominate light absorption. However, nonliving particles affect scattering. This model enhances our understanding of seawater's bio- optical properties, which is crucial for remote sensing and underwater communication. Although the findings are significant, the implications could be more profound because they address various ecological processes.

In their study on underwater optical communication, S. Jaruwatanadilok et al., (2008) [17] apply vector radiative transfer theory for the evaluation of signal attenuation and interference. According to Monte Carlo simulations, light polarization has been shown to improve system reliability while dispersion and distance contribute to signal quality. In their study, indeed, G. Xu et al. (2014) look into the use of wireless sensor networks (WSNs) for monitoring water

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quality in fish farms while focusing on issues pertaining to data transmission and energy management. WSNs facilitate monitoring and conservation initiatives for the environment.

Table 1: Summary Of Related Works In Underwater Health Monitoring And Communication

Reference	Author(s)	Methodology	Advantages and Limitations
Diver Safety and Remote Health Monitoring	CV Vivekanand et al. (2023)	Remote health monitoring via underwater acoustic communication using sensors to monitor vital signs like heart rate and body temperature. SOS messages with GPS in case of emergency	Advantages: Real-time monitoring and quick emergency response. Limitations: Communication challenges and sensor reliability.
Intelligent Diver Health Monitoring System	KAU Menon et al. (2014)	Intelligent system to remotely track health indicators and transmit data via underwater acoustic communication, sending data only in emergencies to conserve power.	Advantages: Power-efficient, transmitting only critical data. Limitations: Limited to abnormal conditions ; gradual health issues missed
Real-time SCUBA Diver Health Monitoring System	S. Gunanandhini et al. (2023)	Real-time health monitoring system for SCUBA divers using wireless communication for vital sign transmission.	Advantages:Continuous monitoring ensures quick responses. Limitations: Testing in real underwater conditions is challenging.
Underwater Software-Defined Radio (SDR) System	A. Netchaev et al. (2016)	Development of underwater SDR systems using electromagnetic waves for wireless telemetry instead of acoustic waves.	Advantages: Flexible across various communication protocols. Limitations: Limited range in certain environments.
High-Speed Optical Communication for Underwater Environments	C. Pontbriand et al. (2008)	High-speed optical communication experiments underwater, demonstrating feasibility at 100-200 meters.	Advantages: Higher data rates and lower latency compared to acoustic communication. Limitations: Signal attenuation due to scattering and absorption.
Undersea Laser Communication Technologies	HG Rao et al. (2016)	Study of underwater optical communication using laser technologies with avalanche photodiodes (APDs) and photomultiplier tubes (PMTs).	Advantages: High-rate data transfer. Limitations: Requires optimal conditions; water clarity impacts communication.
Enhanced UWOC System Using m-QAM-OFDM Modulation	L. Zhang et al. (2018)	Modified m-QAM-OFDM modulation scheme and new frame structure for underwater optical communication	Advantages: Improved BER performance in clear/turbid environments. Limitations: Noise affects reliability under extreme conditions
Li-Fi for Underwater Health Monitoring	R. Latha et al. (2024)	Li-Fi technology for underwater communication, used for diver health monitoring and environmental alerts.	Advantages: High-speed, wireless communication. Limitations: Line-of-sight required
Deep-Sea Survival Assistance and Health Monitoring System	KR Prabha et al. (2023)	Monitors heart rate and brain activity; deploys airbag in emergencies	Advantages: Proactive safety measures. Limitations: Limited to specific emergencies; stable power required.

Subsea Cable Health Monitoring System	N. Srikanth et al. (2017)	Subsea cable health monitoring using sensors to detect damage in real-time.	Advantages: Early damage detection reduces operational disruptions and maintenance costs. Limitations: Limited to specific environments and types of damage.
Wireless Sensor Networks in Structural Health Monitoring	A.B. Noel et al. (2017)	Survey on wireless sensor networks (WSNs) used in structural health monitoring (SHM) for infrastructure safety.	Advantages: Real-time data transmission for detecting structural issues and improving safety. Limitations: Challenges in data reliability, energy consumption, and scalability of WSNs.
Sustainability Monitoring of Marine Fish Farms Using UWSN	J. Lloret et al. (2015)	Proposed underwater wireless sensor network (UWSN) for sustainability monitoring in marine fish farms.	Advantages:Scalable and reliable system for environmental monitoring of fish farms. Limitations:Energy limitations and potential interference due to signal attenuation.
Structural Health Monitoring of Underwater TBM Tunnels	J.P. Yang et al. (2018)	Real-time monitoring system for underwater tunnels using sensors to track vital parameters like displacement and pressure.	Advantages: Early detection of structural risks, enhancing safety and durability of underwater tunnels. Limitations: Limited to certain tunnel environments and does not account for all potential risks.
Monitoring of Underwater Shield Tunnels	X.Tan et al. (2020)	X. Monitoring system for underwater shield tunnels focused on measuring segment joint openings using sensors.	Advantages:Proactive maintenance and risk mitigation for tunnel safety and operational efficiency. Limitations:Limited to measuring joint openings; may miss other types of damage.
Challenges and Vision of Wireless Optical and Acoustic Communication in Underwater Environments	D. Menaka et al. (2022)	Exploration of hybrid optical-acoustic communication systems for underwater applications.	Advantages: Combines high-speed optical communication with reliable acoustic systems. Limitations: Complexity in integration and environmental challenges.

A group-based underwater wireless sensor network for sustainable marine fish farm monitoring was proposed by J. Lloret et al. (2015) [18] which would be able to overcome limitations regarding signal and energy by being able to monitor temperature, oxygen levels, pH, and turbidity.J.P. Yang et al. (2018) [19] propose a real-time monitoring system for TBM-built underwater tunnels, tracking strain, temperature, pressure, and displacement to ensure stability and safety.

Tan et al. (2020) [20] introduced a real-time system for monitoring underwater shield tunnels, measuring segment joint openings by means of displacement sensors conferring active monitoring with the aid of stress gauges. The technology support has been aimed at ensuring that problems are detected at the initial stage, particularly deformities or leakages, which can contribute significantly to proactive maintenance and improve the safety of tunnels (K.Y. Islam et al. 2021) [21] endeavoured to provide a solution to such problems of low data rates, latency, and energy inefficiency, using hybrid optical-acoustic communication systems to achieve eco-friendly underwater communications. The hybrid system makes use of the acoustic communication to provide strength in adverse conditions, but it adds optical communication to provide speed in clean water.

3. PROPOSED SYSTEM

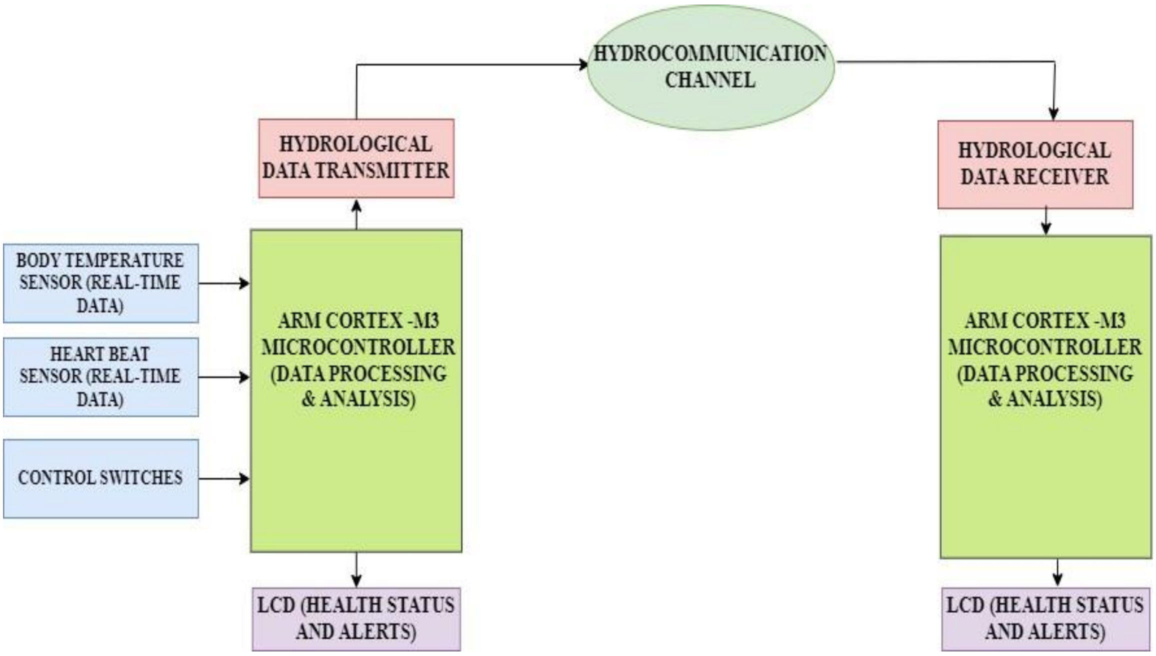

Fig 1: Block Diagram of the Proposed System

The overall system uses a novel approach that integrates sensors, a microcontroller, a display unit, and a communication module with the monitoring of the real-time health of marine workers. The heart of this system will be the 32-bit ARM Cortex-M3 microcontroller. The health parameters of the workers will consist of the continuous readings for body temperature and heart rate by the sensors and relaying this data to the microcontroller for analysis. The ARM microcontroller will analyze data for the normal ranges of health conditions, and, in case of any abnormal value readings like elevated body temperatures or abnormal heart rates, the alert will be issued through an LCD display.

The LCD displays alert messages in the case of any emergencies in addition to displaying real-time health data. Another feature which the system transmits wirelessly in real-time is the water communication module which transmits analysed health data to a surface station. In this manner, the staff monitoring over the water will be provided with constant information regarding the health status of the workers. Working in severe underwater conditions, either with low-frequency radio or acoustic waves since they have been specially designed to perform underwater data transmission, will guarantee that monitoring staff will monitor the health conditions constantly, which will guarantee timely emergency response, enhanced safety and well-being of marine employees in case of any emergency. The centerpiece of the system design is reliability and real-time performance hence ensuring that any emergency is a life-threatening medical emergency thus diagnosed at the least possible time and alerted at the surface so that it could be served with some token help. In addition to the sensor data processing, the ARM Cortex-M3 microprocessor regulates the efficient information transfer between the sensors, the display, and the communication module. This has provided a continuous and uninterrupted possibility of monitors even of adverse underwater environments. The temperature sensor operates in a broad temperature range that provides accurate measurements, whereas where the heart rate sensor records the vital signs to offer the entire health history. The LCD screen constantly displays the health condition of the aquatic worker thus making it easy to make a quick decision. The water communication module can effectively send the health measurements and alarms to the surface monitoring personnel to determine whether one is working underwater.

4. SYSTEM WORK FLOW

This system uses ARM Cortex-M3 microprocessor to monitor the health of marine workers by processing temperature and heart rate sensor data. The micro controller monitors whether the values are in a permissible range or not for the health parameter of workers; an alarm is triggered in case of an anomaly, while warning messages are displayed on an LCD. This data is thereafter transmitted to the surface monitoring station via underwater communication with low- frequency radio waves or acoustic waves. This station receives and decodes the information, indicating the health status of the worker and issuing alarms in case of an emergency so that the support team may take necessary action. enables quick response, wherein real-time health monitoring safe is for the workers even in risky underwater conditions.

First, the system collects data. Data are received from the temperature and heart rate sensors that constantly monitor the vital parameters of the seafarers by the ARM Cortex-M3. The microcontroller is designed to verify such parameters in real-time processing so as to establish whether the parameters of the heart rate and the temperature are in order. If any abnormality occurs, then the system would raise an alarm.

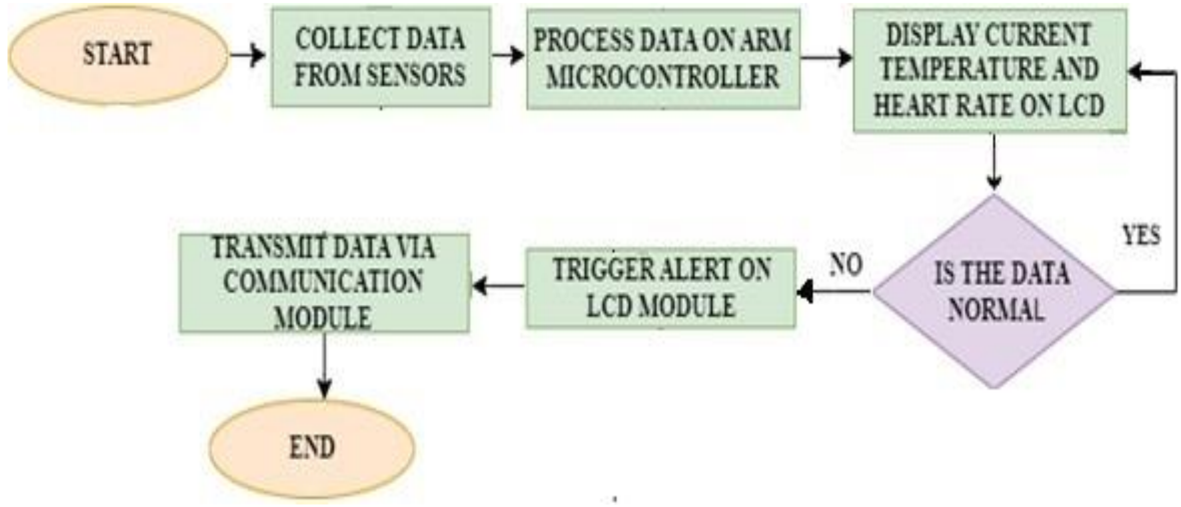

Fig 2: Flow Chart of the Proposed System

After data processing, health indicators of the worker, along with any warning messages, would be displayed on an LCD screen should any critical condition be detected. In the same way, from one module, the health data are sent to a surface communication module, transmitting it to the surface using low-frequency radio waves or acoustic waves. For different situations that arise from decoding the received data, the radiation status of a worker would be displayed by a surface monitoring station. It alerts the team to act immediately in case of critical situations. This guarantees the safety and well-being of a worker in real time, allowing surface staff to respond in a timely manner to those notifications.

5. CONCLUSION

In the context of this research, smart communication technologies for real-time monitoring of workers' health in hazardous underwater conditions were reviewed. It discusses the health monitoring system based upon the ARM Cortex- M3 microcontroller, with heart rate and temperature sensors for accurate joint monitoring of the two parameters. The technology aids in the proactive management of health risks by enabling efficient identification of serious medical conditions and timely alerts to the concerned parties. The system will ensure increased safety in underwater operations by allowing seamless data flow to the surface station, thanks to its reliable underwater communication module. Thus, effective processing of information in the system provides real-time performance and will ensure better safety for the workers with the possibility to build a low-power, scalable input system that could fit various maritime applications.

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