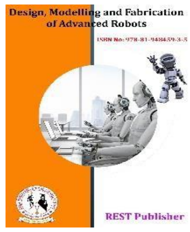
Design, Modelling and Fabrication of Advanced Robots

Vol: 4(2), 2025

REST Publisher; ISBN: 978-81-948459-3-5

Website: http://restpublisher.com/book-series/dmfar/



Development of Smart IoT Based Life Jacket for Workers

***G. Shanmugasundar, R Newton Solomon Raj**

Sairam Institute of Technology, Chennai, Tamil Nadu, India.

***Corresponding Author Email**: Shanmugasundar.mech@sairamit.edu.in

Abstract: *This project presents an IoT-based Smart Life Jacket System designed to enhance personal safety in aquatic environments. The system integrates multiple sensors and modules— temperature sensor, accelerometer, pulse sensor, real-time operating controller (RTOC), water sensor, inflators, Peltier module, light-dependent resistor (LDR) sensor, and LED—to monitor the wearer's physical condition and environmental factors in real-time .Key features include: Real-time Health Monitoring: The pulse sensor and temperature sensor track vital signs to detect abnormal physiological conditions such as hypothermia or unconsciousness. Drowning Detection: The accelerometer detects sudden or abnormal movement patterns indicative of a fall or struggle in water. Automatic Inflation System: When potential drowning or unconsciousness is detected, the RTOC triggers the inflators to deploy and provide buoyancy. Thermal Regulation: The Peltier module provides adaptive thermal assistance to maintain body temperature in cold waters. Environmental Awareness: The water sensor activates the system when submerged, while the LDR sensor adjusts the LED light to improve visibility during rescue operations in low-light conditions. The system transmits data to a remote monitoring platform via IoT protocols, enabling timely rescue operations and continuous tracking. By combining health diagnostics, automated emergency response, and real-time connectivity, this smart life jacket significantly increases safety for swimmers, sailors, and water sports enthusiasts.*

Key words: *Smart Life Jacket, Internet of Things (IoT), Real-Time Monitoring, Pulse Sensor, Temperature Sensor, Accelerometer, Water Sensor, Automatic Inflation System, Peltier Module, Drowning Detection, Thermal Regulation, Light Dependent Resistor (LDR) Sensor, LED Indicator, Rescue Operation, Safety System, Wearable Technology, Remote Monitoring, Health Diagnostics, Aquatic Safety.*

1. INTRODUCTION

In many industrial sectors—such as offshore drilling, marine construction, and water transport— workers are constantly exposed to aquatic hazards. Traditional life jackets provide only passive safety, lacking real-time monitoring and automatic response capabilities. The proposed Smart IoT-based Life Jacket aims to overcome these limitations by integrating intelligent sensing, data analysis, and wireless communication technologies. Through continuous health and environmental monitoring, it ensures that abnormal conditions such as drowning, hypothermia, or loss of consciousness are detected and addressed immediately. The use of IoT technology enables data transmission to a centralized control system for rescue operations, making it suitable for both industrial and recreational applications. It collects real-time data on the worker's physical state and environmental conditions, and sends alerts to supervisors if any abnormal condition is detected. With components like a GPS tracker, heart rate monitor, temperature sensor, and water detection system, the life jacket is capable of detecting falls into water, tracking location, and sensing physiological stress. By providing live updates through cloud platforms and mobile notifications, it enables rapid response to emergencies and enhances overall workplace safety. Workers in marine, construction, and offshore industries face life-threatening risks daily. Traditional life jackets only provide buoyancy and do not offer real-time health monitoring or emergency communication. The Smart IoT-Based Life Jacket addresses these limitations by integrating IoT sensors and wireless communication to enhance worker safety.

2. LITERATURE REVIEW

Several research works and prototype developments have investigated the integration of IoT (Internet of Things), sensor networks, and wearable technologies for personal safety and life-saving applications. The following literature highlights key advancements and existing gaps relevant to the development of a Smart IoT-Based Life

Jacket for Workers:

- **Smart Life Saving Jacket Using IoT (2021):** This study implemented GSM and GPS modules for real-time tracking and automatic alerting of rescue teams during emergencies. The system effectively transmitted the wearer's location when the person was submerged. However, the absence of physiological health monitoring sensors (e.g., heart rate, temperature) limited its application for worker safety in extreme environments.
- **IoT-Based Drowning Detection System (2020):** This research focused primarily on water submersion detection using a simple water sensor and buzzer alarm. While effective in detecting drowning, it lacked advanced features such as temperature regulation, shock or fall detection, and data transmission to cloud-based systems for continuous monitoring.
- **Wearable Health Monitoring Systems (2019):** Various wearable systems integrated temperature and pulse sensors with microcontrollers and IoT platforms for real-time health data collection. These studies highlighted the reliability of health monitoring in wearable devices, laying the foundation for its integration into safety jackets for workers operating in aquatic or industrial environments.
- **Smart Jackets for Marine Workers (2022):** This system used accelerometers and tilt sensors to detect sudden movements or falls in marine environments. It successfully reduced response times during accidents but lacked automatic inflation mechanisms and climate adaptability features such as temperature control.
- **IoT-Based Smart Life Jacket with Automatic Inflation System (2023):** A recent study introduced pressure and motion sensors coupled with a CO_2 inflator system for automatic inflation during drowning incidents. Although effective, it required manual calibration and did not support wireless health data transmission to cloud platforms or mobile applications. 6. **Smart Safety Wear for Industrial Workers (2021):** This project explored the integration of gas sensors, temperature sensors, and heartbeat sensors for workers in hazardous industrial environments. It demonstrated how multi-sensor fusion can enhance safety, but the prototype was not designed for aquatic environments or buoyancy support.
- **IoT-Enabled Smart Marine Safety System (2022):** Developed for fishermen and offshore workers, this system utilized GPS tracking, heartbeat monitoring, and water sensors connected via Blynk IoT. The device successfully alerted rescue teams through SMS and app notifications. However, its power consumption and device weight limited prolonged usage.
- **Integration of Peltier-Based Thermal Control in Wearable Devices (2020) This:** research demonstrated how Peltier modules can maintain body temperature in extreme cold or hot conditions. The concept can be applied to smart life jackets to provide thermal regulation, ensuring comfort and survival during rescue delays.
- **Smart Life Jacket with AI-Based Drowning Prediction (2023):** This recent work combined machine learning algorithms with IoT sensors to predict drowning risk based on abnormal body movement, heart rate, and orientation. It highlighted the potential of AI enhanced predictive safety systems, though implementation complexity remains a challenge.
- **IoT-Based Environmental and Health Monitoring for Offshore Workers (2021) This:** system integrated multi-parameter sensing (temperature, humidity, air quality, pulse rate) using an ESP8266 module and Blynk app for cloud monitoring. The real-time visualization and alert features significantly improved worker safety and supervision efficiency.

3. DESIGN

The system is designed around a Real-Time Operating Controller (RTOC) that acts as the central processing unit. It receives input from various sensors: Pulse Sensor: Monitors the heart rate of the wearer. Temperature Sensor (LM35/DHT11) Measures body temperature and environmental temperature. Accelerometer (ADXL345): Detects motion, tilt, and sudden falls indicating drowning risk. Water Sensor: Detects immersion in water. Peltier Module: Maintains optimal body temperature in cold environments. LDR Sensor and LED: Provide illumination during low-light rescue operations. Inflator Unit: Activated by RTOC to provide buoyancy. All data collected by the sensors are processed by the RTOC and transmitted via IoT connectivity (Blynk App/Wi-Fi using ESP8266 module) for remote monitoring.

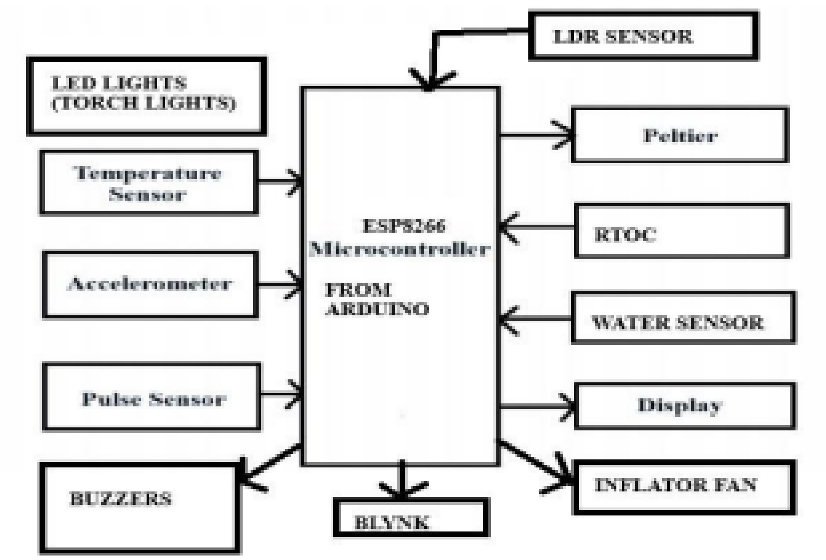


FIGURE 1.

4. CALCULATION

A. Temperature Control

The Peltier module operates on the principle of thermoelectric cooling:

$[Q = \alpha I T - \frac{1}{2} I^2 R - K \Delta T]$

were

(Q) = heat absorbed,

(α) = Seebeck coefficient,

(I) = current,

(R) = resistance,

(K) = thermal conductance,

(ΔT) = temperature difference.

The system maintains a stable body temperature of approximately 36–37°C. B. Pulse Rate Monitoring

The normal pulse rate range is 60–100 bpm. If the sensor detects a pulse below 50 bpm or no signal, the controller identifies the wearer as unconscious and triggers automatic inflation. C. Inflation Mechanism

The inflator is powered by a small CO_2 cartridge, activated through an electronic solenoid valve when the RTOC sends a trigger signal.

Life Jacket Load Calculation

1) Assumptions (change these to match your user or prototype)

- Typical adult mass (wearer): 80 kg.
- Total equipment & jacket mass (sensors, battery, inflator, peltier, casing, etc.): 4.0 kg (you can replace with your measured value).
- Gravitational acceleration: g = 9.81 m/s^2.
- Water density: ρ = 1000 kg/m^3 (fresh water).
- Safety / reserve margin: 25% (multiply required buoyant force by 1.25 to allow margin for waves, clothing, wetting, breathing, etc.).

2) Step-by-step weight → required buoyant force

1. Total mass = wearer + equipment

= 80 kg + 4.0 kg = 84.0 kg.

2. Weight (force due to gravity) = mass × g

= 84.0 × 9.81 N.

* 9.81 × 80 = 9.81 × 8 × 10 = 78.48 × 10 = 784.8 N.

 * 9.81 × 4 = 39.24 N.
 * Sum: 784.8 + 39.24 = 824.04 N.
 So, the body + equipment weight is 824.04 N.
3. Add safety margin (25%): required buoyant force = weight × 1.25
= 824.04 × 1.25.
 * 824.04 × 1 = 824.04
 * 824.04 × 0.25 = 824.04 / 4 = 206.01
 * Sum: 824.04 + 206.01 = **1030.05 N**.
So, design target buoyant force ≈ 1030.05 N** (this is weight + 25% reserve). 3)

Convert buoyant force to displaced volume of water

Buoyant force from displaced water: (F_b = \rho \cdot g \cdot V).
So (V = F_b / (\rho \cdot g)).
Using ρ = 1000 kg/m^3 and g = 9.81 m/s^2:
(V = 1030.05, \text{N} \div (1000 \times 9.81))
* Denominator = 1000 × 9.81 = **9810** (N per m^3).
* V = 1030.05 ÷ 9810 = 0.105000... m^3.
Convert to litres: 1 m^3 = 1000 L → 0.105 m^3 = **105 L**.
Result: To provide 1030.05 N buoyancy you need about **0.105 m^3 = 105 litres of displaced water (air volume in the bladder).

4) Check vs common life-jacket ratings (practical comparison)

Most commercial life jackets are specified by **buoyancy (N)**. Common values: 150 N (typical for 1-person inflatable or foam jacket — basic offshore safety) Volume required: (V = 150 ÷ 9810 = 0.01529; \text{m}^3 = 15.3; \text{L}). 275 N (high-buoyancy jackets for heavier persons / rough conditions)
Volume required: (V = 275 ÷ 9810 = 0.02803; \text{m}^3 = 28.0; \text{L}).
Compare: our calculated 105 L (for full weight + 25% margin) is much larger because that calculation assumes the jacket must completely support the entire weight as if nothing else helps. In reality, a floating human body + lungs already provide buoyancy — life jackets are designed to restore positive buoyancy and correct orientation, not to fully lift the entire body mass from zero.
Therefore, practical approach: design to meet recognized buoyancy classes (150 N or 275 N) that are proven to turn an unconscious person face-up and keep the airway clear — and make sure the system complements the body's natural buoyancy. For industrial/marine workers with heavy equipment or heavy clothing, a higher rating (275 N) is safer.

5) How to size your inflatable bladder for the jacket

If you choose a target inflator buoyancy (for example, 275 N):

- Required air volume (at ambient pressure, i.e., open bladder displacing water): ~28.0 L. * For safety or cold-water heavy clothing, pick larger — e.g., 35–40 L bladder (gives extra margin and accounts for bladder material thickness and partial inflation losses).
- If using pressurized CO_2 inflator, bladder must be sized so that at the operating pressure it contains that air volume when unfolded. (Volume measured at ambient pressure; if you store gas under pressure in a CO_2 canister, it will expand into the bladder to reach ambient pressure and fill the required litres.)

6) Practical design recommendations for your Smart IoT jacket

1. **Select target buoyancy based on user profile:**

 * Default worker jacket (good): 275 N (≈28 L).
 * For heavy clothing/gear or offshore use: consider larger bladder 35–40 L or combine foam + inflation.

2. Inflator sizing:

 * If you want the jacket to provide 28 L, ensure your bladder volume when fully deployed ≥ 28 L (recommend 30–40 L real volume).
 * Choose inflator gas volume / CO_2 canister accordingly (manufacturers list typical bladder volumes per

canister).

3. Redundancy & safety:

* Use foam panels + inflatable bladder: foam gives some passive buoyancy even if inflator fails. A combination reduces required inflation volume and prevents over-reliance on electronics. * Add a second smaller backup CO_2 cartridge or manual inflation tube if budget allows.

4. Power & weight accounting:

* Recompute the earlier arithmetic if your real equipment mass differs. Every extra kg adds 9.81 N of weight; add a safety margin again.

5. Wet vs Saltwater:

* Salt water density ≈ 1025 kg/m³ — reduces required volume slightly. If primarily for seawater use, replace ρ with 1025 and recalc. (E.g., required volume reduces by factor 1000/1025 ≈ 0.975.)

7) Quick summary table (for your 80 kg + 4 kg equipment example)

TABLE 1.

Design target	Buoyant force (N)	Required displaced volume (m³)	Volume (L)
Minimal (equal to weight)	824.04 N	0.08407 m³	84.1 L
With 25% safety	1030.05 N	0.105 m³	105 L
With 25% safety	1030.05 N	0.105 m³	105 L
Standard 275 N lifejacket	275 N	0.02803 m³	28.0 L |

8) Next steps I can do for you (pick any)

- Re-run calculations with your actual wearer mass and measured equipment weights. * Compute required CO_2 canister size and bladder pressure/volume relations.
- Produce a bladder layout (dimensions for a ~30 L bladder).
- Add saltwater correction and show both cases.
- Integrate these numbers into the wiring/power budget so we can size battery and material for buoyancy vs weight.

4. COMPONENTS USED

Component Purpose

Arduino/ESP32 Main microcontroller for processing? Pulse Sensor Monitors heart rate DS18B20 Temperature Measures body temperature Water Sensor Detects immersion in water GPS Module (NEO-6M) Provides location tracking GSM Module (SIM800L) Sends emergency SMS alerts Buzzer & LED Audible & visual emergency signals Li-ion Battery Powers the system Cloud Platform (Blynk) Remote monitoring dashboard

5. PROTOTYPE DESIGN

The prototype consists of a wearable life jacket embedded with sensors and connected to the ESP8266 microcontroller. The jacket continuously monitors health and environmental data and displays it on the IoT dashboard. In case of drowning detection or unconsciousness, the controller automatically activates the inflator and sends an alert notification to the monitoring station or rescue team. The LED provides visibility during night-time rescue.

FIGURE 2.

6. CONCLUSION

The Smart IoT-Based Life Jacket for Workers ensures safety by integrating real-time monitoring, automated rescue response, and environmental adaptation. It provides efficient protection for industrial workers, sailors, and swimmers by minimizing human error during emergencies. Future improvements can include GPS integration for precise location tracking, GSM alerts for offline areas, and solar-based power systems for long-duration operations. The Smart IoT-Based Life Jacket is a groundbreaking safety device that integrates IoT technology to protect workers in hazardous environments. By combining real-time health monitoring, automatic fall detection, and GPS tracking, it ensures faster emergency responses, potentially saving lives. While challenges like battery life and cost exist, the benefits far outweigh the limitations, making it a vital tool for worker safety in marine, construction, and offshore industries. Future enhancements could include solar charging, AI-based anomaly detection, and drone-assisted rescue systems. This IoT-enabled smart life jacket offers a comprehensive and automated safety solution for workers in risky environments. By combining real-time monitoring, environmental adaptation, and emergency response, it significantly reduces response time during accidents and ensures proactive health and safety measures

REFERENCES

[1]. Subhankar Sarkar, "Smart Life Safety Jacket for Rescuers", International Journal of Engineering Research & Technology (IJERT), Vol. 9, Issue 7, 2020.
[2]. Leona Dennis, Preetha S. L., N. S. Anakha, Namitha P. S., Krishna Dev M. P, "Anti-Drowning Inflatable System", International Journal for Research in Applied Science and Engineering Technology (IJRASET), Vol. 10, Issue 5, 2022.
[3]. B. Vamsy Krishna, J. Mano Sri Lakshmi Durga, K. Swathi Sri Anjali, K. V. N. G. S. Prakash, K. Dinesh, "IoT Based Wearable Suit for Real-Time Health Monitoring", MAT Journals – Journal of Embedded Systems and Processing Electronics (JEPSE), 2021.
[4]. M. Fürth, K. Raleigh, T. Duong, D. Zanotto, "SmartPFD: Towards an Actively Controlled Inflatable Life Jacket to Reduce Death at Sea", Sensors Journal (MDPI), Vol. 21, No. 15, 2021.
[5]. Salman Jalalifar, Afsaneh Kashizadeh, Ishmam Mahmood, Andrew Belford, Nicolle Drake, Amir Razmjou, Mohsen Asadnia, "A Smart Multi-Sensor Device to Detect Distress in Swimmers", Sensors (MDPI), Vol. 22, Issue 3, 2022.
[6]. Elżbieta Kałamajska, Jacek Misiurewicz, Jerzy Weremczuk, "Wearable Pulse Oximeter for Swimming Pool Safety", Journal of Sensors and Measurement Science, Vol. 15, No. 4, 2021.
[7]. Renusha K., Sindhumathy S., Sujitha S., Udhayasuriya B, "Intelligent Safety Life Jacket using LoRa Technology", iManager's Journal on Embedded Systems, Vol. 10, Issue 1, 2022.
[8]. Gyoo-Seok Choi, Sung-Jai Choi, Jeong-Jin Kang, Sung-Bae Kim, Ki-Young Lee, Eun-Young Kang, "Positioning Alarm System of Smart Life Jacket Tube", Journal of Engineering and Applied Sciences, Vol. 13, Issue 6, 2018.
[9]. SafePASS Research Team, "Implementation of a Smart Lifejacket for Assisting the Evacuation Process on Large Passenger Ships", Proceedings of the International Conference on Maritime Safety, MDPI, 2021.
[10]. M. A. Rahman, S. M. Ferdous, T. Rahman, "Design of an IoT Based Smart Life Jacket for Drowning Prevention", International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering (IJAREEIE), Vol. 9, Issue 12, 2020.