TPM Vol. 32, No. S4, 2025
ISSN: 1972-6325
https://www.tpmap.org/

Open Access

REAL-TIME HEALTH MONITORING OF MARITIME CREWS USING WEARABLE TECHNOLOGY

PANDIAN MAHADEVAN[1], K. KARTHIK[2]
[1]DEPARTMENT OF NAUTICAL SCIENCE, AMET UNIVERSITY, KANATHUR, TAMILNADU -603112, pandian.mahadevan@ametuniv.ac.in, 0009-0005-5067-5625
[2]DEPARTMENT OF NAUTICAL SCIENCE, AMET INSTITUTE OF SCIENCE AND TECHNOLOGY, CHENGALPET, TAMIL NADU - 603 305, principal@amet-ist.in, 0009-0008-2399-6249

Abstract
This research presents a theoretical framework for decision-making in a networked real-time health administration system for marine transport personnel. The decision-making process is founded on an individual-centered approach for handling ship workers' well-being and security, emphasizing staff members' participation as the primary element in the management loop. Constructs a functional blueprint of a wellness management structure for maritime crews and executes it via a three-phase procedure, including tracking and assessing every worker's health metrics, followed by decision-making. These interrelated processes integrate the tiers of a decentralized innovative health administration system. It outlines suitable strategies for implementing decision support procedures and details a potential way to assess generated information and make judgments using fuzzy pattern recognition. Modelling of a fuzzy ideal picture and fuzzy actual images representing a worker's health state has been constructed, together with an algorithm for evaluating the departure of produced medical variables from the usual range. The document consolidates the regulations for establishing the knowledge foundations of a dispersed innovative system for distant constant oversight. Integrating this foundation into the automated architectures is expected to help assess the health patterns of ship staff members and facilitate responsible choices to address specific issues.
Keywords – Health Monitoring, Maritime, Wearable Technology, Crews

1. INTRODUCTION

Incidents of impact, grasping, and falls have been documented as factors adversely affecting the health of container lashers at work [1]. This project aims to provide requirements for a device to monitor dock employees' health and analyze risks, including technological and design factors. The current recommendations for worker risk evaluation are inadequate due to significant heterogeneity, willingness, and a lack of job uniformity [12]. Physiotherapists frequently evaluate the range of movement of dockworkers, aiming to achieve mobility objectives and measure mobility according to their findings. Biomechanical risk evaluations predominantly rely on observational and intuitive methods, lacking the utilization of human motion recording technology [2]. Instruments for monitoring have been suggested, adopted, and utilized in the healthcare industry as instruments for risk evaluation. Motion analysis, utilizing kinematic and dynamic information obtained from wearable motion-capturing devices, facilitates risk estimation through quantifiable and changing data, enabling more accurate assessment in actual work environments. Several sensors and methods are available, each with specifications, metrics, and limitations [11].

Wearable movement tracking devices are utilized in sports like golf to enhance technique immediately [3][19]. Training using recording equipment enhances workers' knowledge of incorrect techniques. This is particularly pertinent since a discrepancy was identified between the acquired practices at the education facility and the behaviors implemented on the work floor [4].

Wearables facilitate recovery, an ongoing procedure that enables patients to regain their functional capacities to baseline levels. To achieve this objective, patients' actions must be consistently observed and adjusted. Workers with recurring or healing injuries might be thoroughly followed throughout their recuperation. Maritime enterprises might utilize quantifiable and dynamic biomechanical information before, during, and after operations [13].

This circumstance has resulted in the birth of notions such as "human beings factor" and "tiredness" in the maritime context. Analysis of marine transport events indicates that 80-90% are attributable to human actions [14]. The incidents primarily arise from errors and misjudgments by decision-makers throughout ship operations, rather than technical malfunctions. The psychological and psychophysiological strain experienced by sailors, particularly ship navigation commanders and captains, is the primary cause of maritime mishaps. The research presents a conceptual framework for tracking and assessing the psychological state of ship employees before and after their shifts to prevent maritime transport disasters [5]. Industry 4.0, defined by technological advancements such as the Internet of Things (IoT), nanotechnologies, biological technology, and Artificial Intelligence (AI), has fostered novel research trends to address these challenges [6]. The paper presents a novel strategy emphasizing the human element and IoT integration to avert shipwrecks. It provides a methodology for an innovative system to assess the health state of the ship crew utilizing IoT technology [15].

2. ASSESSMENT OF WEARABLE SENSORS

The Dielectric Elastomer Sensors (DESs) evaluation relies on a motion tracking system. It demonstrated commendable laboratory accuracy, reproducibility (0.7%), excellent linearity (0.13%), and sensitivity (0.007V/mm). High linearity denotes the proportional relationship between the observed voltage variation and the corresponding change in angle or bend [18]. The attributes of the DES fulfill the prospective criteria for wrist motion assessments. Seamlessly incorporated into clothes, DES-based structures exhibit exceptional unobtrusiveness, sensing capabilities, safety, and durability within a controlled setting. They encounter some significant drawbacks when utilized in uncontrolled environments. The initial factor is measuring inaccuracies resulting from the movement and distortion of clothes [16]. Tight, stretchy clothing is often regarded as a solution to this issue. However, this technique is compromised when the fitted garment elongates with the sensors rather than only the sensors themselves.

In practical situations when persons are tugged at their sleeves, removed, or otherwise adjust their clothes, the poor tolerances for movement of DES-based tracking devices, due to a position repeatable accuracy of 0.4 cm, would pose a significant obstacle. Secondly, elevated degrees of customisation would be necessary for each individual due to varying forearm and wrist proportions. After establishing a customized arrangement, each sensor must be positioned in the identical location within a tolerance of 6 mm for all subsequent use cases [9].

Finally, a direct connection to the skin is required. In that case, maritime workers must affix twelve individual sensors onto their wrists and armpits, since every aspect of motion necessitates one sensor for both forearms. This is an expectation beyond their capabilities, particularly if the device is to evolve into a comprehensive upper body surveillance system. Customization presents obstacles to extensive implementation and daily utilization [17].

The bend sensors produced by Flexpoint Sensor Solutions were examined, yielding four distinct observations centered on monitoring elbow flexion and extension. This work presents a final study in which a Flexpoint Sensor has been integrated into a smart textile test, with the sensor affixed to the proximal side. The data gathered was evaluated with Kinovea software to assess the reproducibility of joint angle measures during elbow flexion and extension [10].

Multifunctional Inertial Measurement Units (IMUs) are utilized for biomechanical risk evaluation in indoor and outdoor environments [7]. They have demonstrated competencies in this application. They're lightweight and user-friendly, although they occasionally resist magnetic fields. This final component is crucial in a marine context, particularly for dock employees engaged in the lashing and de-lashing of boxes.

Wearable detectors, such as IMU sensors, can be incorporated into smart bands or clothes for dockworkers. Yet, current mounting methods demonstrate discomfort. These factors must be considered while building a gadget to track dock employees without compromising efficiency.

Considering the benefits and limitations of each sensor category, it was determined that modern IMU-based movement tracking systems provide an extra benefit over DES and bend detectors. Compared to the other two sensor kinds, they exhibit fewer challenges related to location reproducibility and are adjusted more easily. IMU chaining facilitates straightforward extension to an upward or full-body measurement system. The limits of IMUs must be carefully considered, since electromagnetic radiation can significantly impact their performance and lead to drift as time passes [8].

3. PROPOSED REAL-TIME HEALTH MONITORING USING WEARABLE TECHNOLOGIES

All physical, psychological, healthcare, social, manufacturing, and ecological factors intrinsic to the maritime environment serve as possible sources of maritime journeys, influence the human activity structure, and result in hazardous behaviors by those on board. Variations in personnel's health while executing their responsibilities and residing aboard the ship might result in dangerous behavior, decisions, psychological problems, and ultimately, erroneous judgments and mishaps. The erroneous judgments crew members make are strongly influenced by their physical status, which impacts how they act and perform their job responsibilities. Their physiological state is a crucial element of the ship's staff and a primary factor that directly influences their professional actions.

Implementing steps to safeguard the wellness of staff members enables them to effectively manage their mental, physical, and social circumstances, enhance their operational capacities, and, crucially, make improved judgments

in atypical scenarios. In this regard, a design is presented to routinely monitor the health state of workers in their place of employment (before and after their shifts) to prevent maritime mishaps.
The structure of the real-time health care system for shift employees aboard ships is centralized, with three regionally scattered levels, each serving as a targeted intelligence Information Systems (IS) with specific purposes and functions. All three levels are consolidated into a unified decision-supporting process, ensuring the system operates cohesively.
Implementing an IoT-based platform can concurrently transfer sensed data to many contextual control hubs (servers) situated downward (at the same level) and vertically within the control structure. In this scenario, every person of the ship's crew operates as a biological being outfitted with body-worn and wearable technologies that provide information based on their original intent.

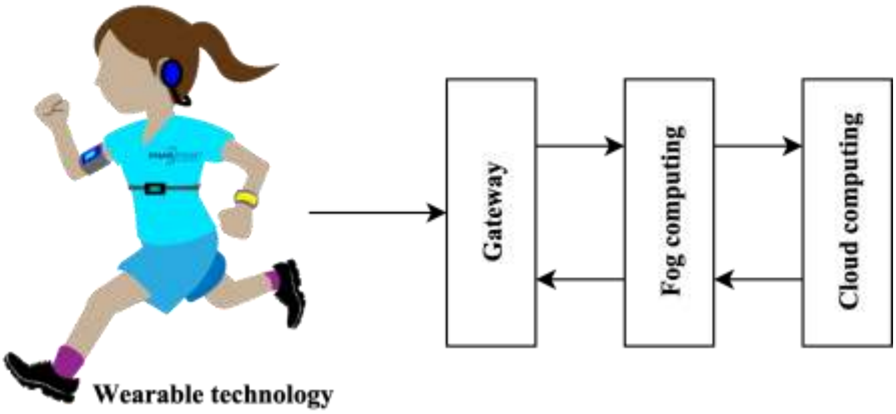

Fig. 1. Wearable technology-based health monitoring

This equipment (security tools) facilitates human contact with surroundings and can capture, accumulate, process, and transfer data. Intelligent sensors provide localized data processing aboard the vessel and ensure dependable and secure immediate delivery of this information to situational centers or rescue teams via several non-hierarchical control tiers.
The IoT scientific environment, alongside tangible gadgets, computer systems, and analytical instruments, integrates comprehensive operations within the suggested design of the ship workers' health administration system into systematically divided computing stages: Dew computation, Fog computation, and cloud computation.
The initial layer of Distributed Intelligent Systems (DIS) emphasizes maritime personnel's health and security surveillance. This layer implements immediate actions to coordinate rescue efforts of a worker at the accident site and administer first aid. Data gathering, processing, and evaluation are conducted using Dew computing, facilitating immediate decision-making and guaranteeing minimal latency in data handling. Information about workers, captured by detectors and Radio Frequency Identity RFID via a worn device and a cellphone functioning as a gateway, is communicated wirelessly or via cable to the ship's Local Situation Centre for Disaster Responses (LSCER). It is a digital platform for individuals accountable for the health and security of maritime employees. This is a desktop computer (Dew information centre) intended to gather and evaluate incoming information on the well-being and protection of workers throughout their shifts. The IoT consistently contrasts the normative (regard), starting (pre-shift), and current (real-time) values of observed health metrics and surrounding environmental elements of employees. If all maritime worker and environmental data remains within permissible parameters, no information is transmitted to the local computers (Dew information center). When the numbers of health metrics, locations, and variables captured by sensors exceed the normal range, the information is transmitted to a local connected device for processing, analyzing, and making choices. The IoT application, utilizing specialized analytical instruments and intelligent computations, detects alterations in worker health and violations in environmental variables from established norms, providing solutions for their rectification.
The additional tier of the DIS network structure is intended for the distant health and security surveillance of personnel aboard ships from the closest coastal situation office. The acquisition of data produced at the sensor layer and its analytical manufacturing, decision-making, and short-term storage are executed in real time via Fog computing. The innovative IoT infrastructure DIS provides the following functions in a Fog surroundings: 1) Recognizing and analyzing immediate information from the Dew layer without direct interaction among the vessel and the Cloud, 2) Utilizing Fog statistics findings to make decisions regarding each obtained circumstance and transmitting the corresponding control actions for carrying out to the Dew layer, 3) Sending information to the Cloud that significantly deviates from established norms.

The third level of the DIS network framework, Cloud Computing, is intended to oversee the individual medical trajectories of shift employees. The resolution of this issue relies on systematic data collection and aggregation from diverse sources about the security and health characteristics of employees, as well as the establishment of comprehensive databases documenting the chronological alterations in the essential physiological metrics of each employee. These records are housed in a personal cloud and facilitate decision-making at the highest tier of the shipping firm.

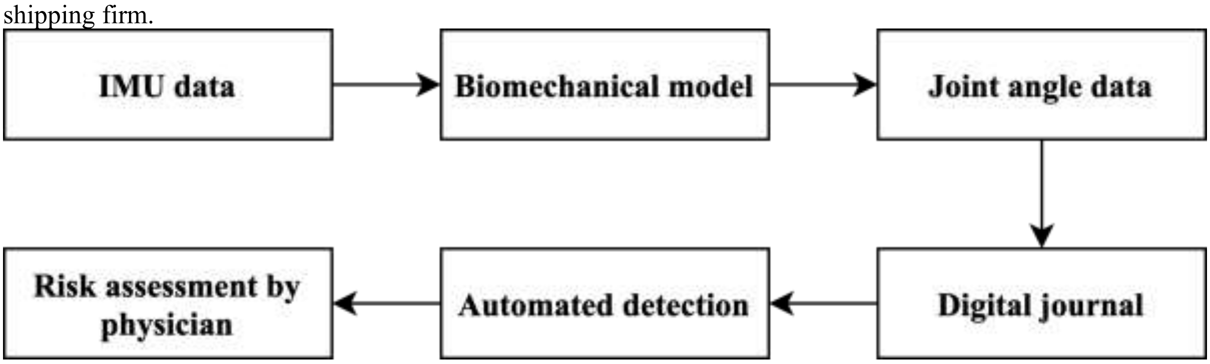

Fig. 2. Workflow pipeline

Fig. 2 illustrates the pipeline for data acquisition and management. The suggested small glove idea obtains information such as angular rotation, velocity, direction, and time. When integrated with a biomechanical modeling of the hand, this information enables the derivation of joint angle values. This information will be recorded in a journal for every employee (structure). The equipment will continually monitor for indications. Physiotherapists can conduct risk evaluations and implement intervention techniques to enhance health through a website.

4. FROM APPLICATIONS TO TESTING AND FROM ASSESSMENT TO THERAPY

Following an elucidation of how a remote mental state diagnostic system might benefit a mariner, the research ends by outlining the entire procedure. A corporation must determine whether to supply wearable gadgets to all employees involved in a cruise or to use criteria for choosing. The criterion must encompass several aspects, including the duration of the seafarer's aboard tenure, their experience, age, prior records, and current psychological assessment by specialists before embarkation. It is crucial to evaluate these elements since they encompass a seafarer's attributes and the occupational setting. Criteria differ; if criteria are selected for application, the optimal combination will depend on the seafarer's expertise and duration at sea. It might be prudent to offer a seafarer, embarking on a voyage beyond three weeks and possessing limited expertise, a wearable gadget for keeping track of their psychological state.

Considering the sale of smart gadgets, it is essential to contemplate how seafarers will be provided with them. The optimal strategy involves staffing agencies or shipping businesses supplying them before embarkation. Upon the conclusion of the seafarer's journey, they will either transfer the mobile gadget to the incoming passenger or return it to the staffing agency or transportation firm.

Data collection on their psychological state commences upon equipping seafarers with a connected gadget. The seafarer will monitor vital signs daily, including body temperatures and heart rate, relaying the findings to the shipping business's databases. Algorithms utilizing cognitive networks, as previously mentioned, will analyze the data to elucidate the seafarer's state of mind. The outputs will be electronically archived for simple retrieval by officially designated persons from a shipping firm's staff and the division, considering the delicate nature of this private information. Analytics is extracted, and specific alerts can be issued when outcomes deviate from mental health guidelines. After a warning, the individual responsible solicited the assistance of an expert in mental health. Shipping corporations are encouraged to employ specialized psychologists with access to the mariners' mental health information. The psychologists initiate the diagnosis, and online therapy can be arranged for the seafarer if required. Following the COVID-19 outbreak, internet counseling has proliferated, with several sites such as BetterHelp, Talk Space, Amwell, and various telehealth efforts offering psychological specialists' services to individuals. Psychological professionals have familiarized themselves with this method.

5. CONCLUSION

The likelihood of a single worker making erroneous judgments is strongly influenced by their health state, which dictates their behavior and activities throughout their shift on the vessel. An approach utilizing fuzzy pattern identification algorithms was presented to ascertain the present medical condition of employees, enabling the automatic analysis of provided information and the synthesis of a diagnostic answer.

This technology enables real-time assessment of each worker's health state

- autonomously render decisions in real-time based on the crucial circumstances

- Assess the health danger level of the urgent circumstance
- Get real-time data on the physical state of every worker
- Methodically gather personal health information for every worker and establish a dynamic registry.

Incorporating this foundation into the framework of an innovative personnel well-being management structure as a changing database component, alongside the integrated analytical analysis of both current and historical information, will enable:

- an objective evaluation of trends in the health status of every employee
- Updated and impartial decision-making is needed to address issues adversely impacting maritime workers' health in the short, medium, and long term.

REFERENCES

1. Bitzas, S., Ma, S., Pesanelli, K., & Zaia, A. M. (2022). Risk factors and impacts of slips, trips, and falls in janitorial populations: A literature review: Applied Ergonomics, 102, 103745.
2. Ibragimov, S., Mavlyanova, R., Burieva, N., Abdusatorov, S., Mengliboev, A., Nazirov, B., Norbotaev, I., & Zokirov, K. (2024). Investigating the Effects of Aquatic Pollutants on Human Health. International Journal of Aquatic Research and Environmental Studies, 4(S1), 107-112. https://doi.org/10.70102/IJARES/V4S1/18
3. Kim, M., & Park, S. (2024). Enhancing the accuracy and convenience of golf swing tracking with a wrist-worn single inertial sensor. Scientific Reports, 14(1), 9201.
4. Padhye, I., & Shrivastav, P. (2024). The Role of Pharmacists in Optimizing Medication Regimens for Patients with Polypharmacy. Clinical Journal for Medicine, Health and Pharmacy, 2(2), 41-50.
5. Brooks, S. K., & Greenberg, N. (2022). Mental health and psychological well-being of maritime personnel: a systematic review. BMC psychology, 10(1), 139.
6. Pragadeswaran, S., Vasanthi, M., Boopathy, E. V., Suthakaran, S., Madhumitha, S., Ragupathi, N., Nikesh, R., & Devi, R. P. (2024). Optimizing VLSI architecture with carry look ahead technology based high-speed, inexact speculative adder. Archives for Technical Sciences, 2(31), 220–229. https://doi.org/10.70102/afts.2024.1631.220
7. Baklouti, S., Chaker, A., Rezgui, T., Sahbani, A., Bennour, S., & Laribi, M. A. (2024). A Novel IMU-Based System for Work-Related Musculoskeletal Disorders Risk Assessment. Sensors, 24(11), 3419.
8. Iyer, R., & Deshpande, N. (2024). Nanotechnology and their Applications in Chiral and Achiral Separating Mechanisms. Engineering Perspectives in Filtration and Separation, 2(4), 7-13.
9. Imam, J. M., Mokhtar, N., Hatta, S. M., Rashdan, M., Salman, M., Khandaker, M. U., & Islam, M. A. (2024). Review Selection and Pathways to Next Generation Innovations of Speed Over Ground (SOG) Measurement Technologies to Overcome Harsh Conditions and Technological Limitations. IEEE Sensors Journal.
10. Thomas, L., & Iyer, R. (2024). The Role of Unified Medical Terminology in Reducing Clinical Miscommunication and Errors. Global Journal of Medical Terminology Research and Informatics, 2(3), 12-15.
11. Volkert, D., Beck, A. M., Cederholm, T., Cruz-Jentoft, A., Hooper, L., Kiesswetter, E., ... & Bischoff, S. C. (2022). ESPEN practical guideline: Clinical nutrition and hydration in geriatrics. Clinical Nutrition, 41(4), 958-989.
12. Sumithra, S., & Sakshi, S. (2024). Understanding Digital Library Use among STEM and Non-STEM Students: Insights from PLS-SEM MGA. Indian Journal of Information Sources and Services, 14(2), 1–10. https://doi.org/10.51983/ijiss-2024.14.2.01
13. McDevitt, S., Hernandez, H., Hicks, J., Lowell, R., Bentahaikt, H., Burch, R., ... & Anderson, B. (2022). Wearables for biomechanical performance optimization and risk assessment in industrial and sports applications. Bioengineering, 9(1), 33.
14. Hussain, I., & Qureshi, A. (2024). Gender-Inclusive Energy Transitions: Empowering Women in Renewable Energy Sectors. International Journal of SDG's Prospects and Breakthroughs, 2(2), 7-9.
15. Jagatheesaperumal, S. K., Rahouti, M., Ahmad, K., Al-Fuqaha, A., & Guizani, M. (2021). The duo of artificial intelligence and big data for industry 4.0: Applications, techniques, challenges, and future research directions. IEEE Internet of Things Journal, 9(15), 12861-12885.
16. Sanjeevi, B., Khadouri, S. S. S. A., Arokiasamy, A. R. A., & Raman, A. (2024). Adaptive Mobility and Reliability-based Routing Protocol for Smart Healthcare Management Systems in Vehicular Ad-hoc Networks. Journal of Wireless Mobile Networks, Ubiquitous Computing, and Dependable Applications, 15(3), 150-159. https://doi.org/10.58346/JOWUA.2024.I3.011

17. Tan, W., Sarmiento, J., & Rosales, C. A. (2024). Exploring the Performance Impact of Neural Network Optimization on Energy Analysis of Biosensor. Natural and Engineering Sciences, 9(2), 164-183. https://doi.org/10.28978/nesciences.1569280
18. Alam, R., & Subramanian, V. (2024). Fertility Decline in High-income Countries: Socioeconomic Drivers and Cultural Resistance. Progression Journal of Human Demography and Anthropology, 2(2), 1-4.
19. Veerappan, S. (2023). The Role of Digital Ecosystems in Digital Transformation: A Study of How Firms Collaborate and Compete. Global Perspectives in Management, 1(1), 78-89.
20. Prasath, C. A. (2025). Adaptive filtering techniques for real-time audio signal enhancement in noisy environments. National Journal of Signal and Image Processing, 1(1), 26–33.
21. Poornimadarshini, S. (2025). Robust audio signal enhancement using hybrid spectral-temporal deep learning models in noisy environments. National Journal of Speech and Audio Processing, 1(1), 30–36.
22. Arun Prasath, C. (2025). Performance analysis of induction motor drives under nonlinear load conditions. National Journal of Electrical Electronics and Automation Technologies, 1(1), 48–54.
23. Fang, W., Yong, Z., & Hua, L. (2024). Cultural Impacts of Mass Tourism at Hidden Costs for Local Communities in 2025. Journal of Tourism, Culture, and Management Studies, 1(2), 50-60.
24. Kowalski, T., & Nowak, M. (2024). The Impact of Digital Transformation on Quality Assurance in Healthcare Systems. National Journal of Quality, Innovation, and Business Excellence, 1(2), 1-12.
25. Kavitha, M. (2025). Hybrid AI-mathematical modeling approach for predictive maintenance in rotating machinery systems. Journal of Applied Mathematical Models in Engineering, 1(1), 1–8.
26. KUSTINA, K. T., DEWI, P. P., LAKSMI P, K. W., & Yumi Arya Kusuma DEWI, N. K. (2025). Increasing Business Growth Through Strategy Competency with Innovation as A Mediation Variable. Quality-Access to Success, 26(206).