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Hybrid Approach Using Machine Learning and IOT for Soldier Rescue : A Review

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Abstract:- Despite the well-established influence of various factors on a soldier's burden – including environment, physical exertion, equipment design, and mental stress – our current understanding is largely based on studies conducted in controlled lab settings, focusing solely on the weight of carried equipment. This limited scope hinders a comprehensive picture of how these combined burdens impact a soldier's ability to survive on the battlefield, encompassing factors like performance, health, and vulnerability to enemy attacks. To bridge this gap and gain a more holistic understanding, field-based methods for capturing soldier movement are crucial. In this vein, we've developed a novel human activity recognition system. Trained using data collected from a single sensor placed on a soldier's upper back, the system can identify eleven distinct tactical movement patterns commonly employed by soldiers in the field. This advancement paves the way for a more nuanced understanding of how various burden factors interact and influence a soldier's effectiveness and safety in real-world scenarios. Using K- Nearest Neighbour, SVM Classifier, Logistic Regression, Naïve Bayer algorithms real-world constraints are forced, and class labels are expanded. This project is based on health monitoring and tracking system for soldiers. The proposed system can be mounted on the soldier's jacket to track their health status and current locating using GPS. This information will be transmitted to the control room through IOT and ML. The proposed system comprises of tiny wearable physiological equipment's, sensors, transmission modules. Hence, with the use of the proposed equipment, it is possible to implement a low-cost mechanism to protect the valuable human life on the battlefield. It also includes about securing of data of soldiers in the cloud. This new method offers a powerful tool for military leaders and scientists. By collecting real-world data on soldier burden, it allows them to quantify the complex factors affecting soldier performance (the tradespace). This data acts as valuable pre-processing for other technologies, ultimately enabling data-driven decisions to optimize soldier well-being, minimize risk, and maximize mission success.

Keywords:- *Activity Recognition, Performance, LM35 Sensor, Heartbeat Sensor, Military, Wearables.*

I. INTRODUCTION

Soldiers are not robots confined to controlled environments. During training and deployment, they execute a diverse repertoire of tactical movements while shouldering a significant burden. This burden extends far beyond the weight they carry (body-borne load mass). It encompasses a complex interplay of factors like the physical demands of the movement (metabolic demands), the environment they operate in (temperature, terrain), the characteristics of their equipment (weight distribution, breathability, etc.), and even the psychological pressures they face (stress of combat). However, the field of biomechanics studying soldier movement has largely relied on a limited approach. Traditionally, research takes place in controlled indoor laboratories, often focusing solely on the impact of body-borne load mass on movement patterns. While these studies provide valuable insights into the fundamental mechanics of movement under load, they suffer from a critical limitation: they fail to capture the real-world complexities soldiers face in the field. The controlled lab environment lacks the dynamic interplay of factors present in operational settings. Here, soldiers operate under the specific demands of a mission, the ever-present threat of enemy action, the constraints of the environment, and the guidance of their commanders. These factors heavily influence the types of movements soldiers perform and how they perform them. As a result, the negative effects of heavy loads observed in lab studies might not fully translate to the realities of combat situations. Therefore, to gain a more accurate understanding of how soldier burden impacts movement in the operational environment, a paradigm shift is necessary. We need to move beyond the limitations of lab studies and embrace a new approach: field-based motion capture. This method would allow researchers to collect data directly in the field, under the true conditions soldiers encounter during training and deployment. This shift would provide a more comprehensive picture of soldier movement and its interaction with the various aspects of soldier burden. Ultimately, this would lead to a deeper understanding of soldier effectiveness and safety in real-world scenarios, allowing us to develop better strategies and equipment to optimize their performance and well-being. Traditional biomechanical research has relied on bulky and cumbersome equipment, limiting data collection to controlled lab settings. However, the advancements in Internet of Things (IoT) and Machine

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Learning (ML) offer a more promising approach for field-based soldier motion capture. Imagine a network of tiny wearable sensors – the Internet of Things – seamlessly integrated into a soldier's uniform. These sensors could include accelerometers, gyroscopes, and magnetometers, similar to the Inertial Measurement Units (IMUs) previously mentioned. However, the advantage of IoT lies in its ability to connect these sensors and transmit data wirelessly. This allows for real-time data collection and analysis, providing a much richer picture of soldier movement in the field. Here's where Machine Learning comes in. By training ML algorithms on this sensor data, we can unlock powerful capabilities. The algorithms can learn to identify various tactical movement patterns performed by soldiers, even with just a single sensor placed on their upper back. This eliminates the need for complex calibration procedures associated with traditional biomechanical models. While this approach might not capture the full range of kinematic details (gross kinematic differences), it offers significant advantages for field deployment. The small size and low cost of these sensors allow for simultaneous data collection from multiple soldiers, making large-scale studies more feasible. More importantly, the collected data can be used to assess not just performance degradation due to soldier burden, but also susceptibility to injuries and fatigue. Building upon previous military research that successfully utilized single IMUs for similar purposes, this IoT and ML-powered approach holds immense potential. It can revolutionize our understanding of soldier movement in real-world scenarios, paving the way for optimizing soldier performance, minimizing risks, and ultimately, ensuring mission success [2].

Human activity recognition (HAR) has become a powerful tool within machine learning, offering the ability to identify movement patterns using data from wearable sensors. This technology can be harnessed for military applications through the Internet of Things (IoT) and Machine Learning (ML), replacing the bulkier IMUs (Inertial Measurement Units) traditionally used. Imagine a network of tiny sensors – the IoT – seamlessly integrated into a soldier's uniform. These sensors could include an LM35 (or similar temperature sensor) alongside accelerometers and gyroscopes, providing valuable data about movement and environmental conditions. Unlike IMUs, which require complex calibration, these sensors can be easily deployed in the field. The magic happens when we combine this sensor data with ML algorithms. By training these algorithms on the collected data, we can unlock the ability to recognize a wide range of tactical movements performed by soldiers. Even with a single sensor on the upper back, the ML can identify these patterns with remarkable accuracy. While this approach might not capture every minute detail of movement, it offers significant advantages for real-world use. The small size and low cost of these sensors allow for simultaneous data collection from multiple soldiers, making large-scale studies more feasible. This data can then be used for a variety of purposes beyond just recognizing activities. Building on the success of HAR research, this approach using IoT and ML can revolutionize military research. We can use it to study soldier fatigue by analyzing activities that lead to sustained heart rate or performance decline. It can be used to assess ergonomics by tracking task frequency, rest periods, and interaction with objects. Additionally, it can be used to analyze team-based interactions, digitize training drills for visual analysis, and even calculate exposure time during simulated combat scenarios. In essence, this technology has the potential to significantly advance various fields within defense science, ultimately leading to a deeper understanding of soldier well-being, performance, and survivability [2] [13].

This study investigated the effectiveness of a single sensor network, leveraging Machine Learning (ML) algorithms, to recognize critical soldier movements and calculate relevant metrics. We designed various ML algorithms to identify operationally important movement patterns using data from a single LM35 sensor (or similar temperature sensor) integrated into the soldier's uniform. Data was collected in two settings: a controlled indoor environment and an outdoor simulated combat drill involving a two-person team attacking a 60-meter section.

Three types of ML algorithms were explored: 1) Random Forest Classifier 2) Logistic Regression, and 3) XG Boost. We trained these algorithms using three approaches: data specific to the indoor environment, data specific to the combat drill, and a combined approach using data from both settings. The predictions from the ML algorithm Random Forest Classifier were then processed through a two-step logical function. This ensured the predictions aligned with real-world constraints and allowed us to expand the number of recognizable movements. We evaluated the performance of our ML models using standard machine learning metrics like accuracy and F1-scores. Additionally, we compared the calculated metrics that affect a soldier's survivability (exposure time, vulnerability to enemy attacks) using both the predicted labels and the actual labels from the test participants.

II. RELATED WORKS

Compared with many current literatures devoted to summarizing Soldier Survivability Tradespace , this paper makes the following contribution:

Mathew P Mavor, Victor C.H Chan et al presented a strategy where they developed a system using a single sensor on a soldier's back to identify their movements. This system, which uses advanced machine learning, can recognize 11 common soldier actions and even account for real-world limitations to increase accuracy. We tested the system in three settings: indoors, during a simulated outdoor attack, and a combination of both. In all cases, the system identified movements with an average accuracy of 90%. Even better, using the system's predictions, we could calculate important metrics related to soldier safety (like exposure time) almost as accurately as using real data [1].

Pavan Mankal, Sushmita, Ummeaiman, Shweta et al presented the strategy where they used GPS and GSM Modules, Arduino software in which the health parameters are seen in the app called Thingview. Location can also be tracked using google map. But there was Low manufacturing cost, which often means limited code size and Problems due to networks [2].

Vinit Patel et al presented that Current methods only track location, leaving health unmonitored. This new system combines wearable sensors, GPS, and wireless communication. It tracks vital signs (heart rate, temperature) and location in real-time. Data is sent to a central hub that monitors for abnormalities and triggers alerts. GPS allows commanders to see troop locations precisely. An emergency button sends soldiers' location directly to a control room for faster medical response. This comprehensive system offers a more complete picture of soldier safety [3].

Benjamin Dubetsky et al presented that Object classification is a tech that can make military missions safer and more efficient. Imagine using drones and robots instead of soldiers for risky tasks. This project aims to build a system that can automatically identify and track people during search and rescue missions. This could save lives by letting robots take on dangerous jobs, while soldiers focus on areas that need them most [4].

Raghu Jayaramu et al presented the strategy where system tackles that by offering real-time tracking and health monitoring. It uses GPS to pinpoint location and sensors to measure vitals like heart rate and temperature. This data gets sent wirelessly (GSM) to a central hub, allowing commanders to monitor soldiers' well-being and quickly launch rescue missions if needed. This cost-effective solution helps ensure soldier safety with minimal delay [5].

Bhargav Jethwa et al presents that WSN-based environmental and health monitoring approach in which sensor data is processed using robust and stable algorithm implemented in controller. These processed data are then sent to the base station via low-cost, low- power and secure communication links provided by a LoRa network infrastructure instead of cellular networks, since, they are either absent or doesn't allow data transmission in warzone or remote areas. We focus on monitoring environmental factors such as temperature, humidity, air pressure, air quality; physical factors such as motion, position, geographic location and health parameters like ECG (electro cardiograph), blood oxygen level, body temperature. Moreover, camera and microphone are used to monitor any undesirable situation of soldier. The aim of the system is to reduce the response time for any emergencies with the use of embedded system and WBASN, while being power efficient [6].

Govarthan R et al presents compact system to monitor their heart rate, temperature, and location. Tiny sensors pick up this data, and a GPS tracker keeps tabs on where they are. Unlike unreliable Wi-Fi, the system uses a shorter-range network to send data securely to a nearby base station. This data is then uploaded to the cloud for analysis. The goal? Faster rescues and better soldier protection by keeping a close eye on their health and location [7].

Fazal Mahamood et al presents a new system using NB-IoT technology to keep them safe. Imagine a system that tracks a soldier's location and health data (heart rate, environment) anywhere in the world, even in hostile territories or remote locations. This NB-IoT system, combined with satellite communication, can collect data securely and reliably, even where traditional networks fail. Think of it as a guardian angel for soldiers, providing critical information for faster rescues and better decision-making in any situation [8].

Sujitha V et al presents a system uses GPS for location tracking, along with health sensors like heart rate and temperature monitors for real-time health data. It even includes a bomb detector and panic button for emergencies. All this data gets processed by a nearby personal server to ensure clean signals, then sent wirelessly to a base station. Soldiers can also directly communicate injuries using a built-in ESP32 module. The coolest part? The system can even predict soldier location and health in enemy territory, sending alerts to both the base station and nearby troops via a special mobile app. This means faster response times, better decisions, and ultimately, safer soldiers [9].

Rakshana Mohammed Ismail et al presents the system that tracks location (GPS) and health (heart rate, temperature) with real-time sensors. It even packs a bomb detector and panic button! Data gets cleaned by a nearby server before zipping wirelessly to base. Soldiers can report injuries directly, and the coolest feature? It predicts location and health in enemy territory, sending alerts for faster rescues via a mobile app. This keeps soldiers safer with quicker response times and better decisions [10].

C Ashok Kumar et al presents the system that uses a network of tiny sensors (WSN) to track their environment (think temperature, stress) and fitness (heart rate). The data gets processed reliably and securely using Internet of Things (IoT) technology. Imagine tiny wearable devices and sensors collecting this information, then sending it to a control room for analysis. This low-cost system can help safeguard valuable lives on the battlefield [11].

Dharam Buddhi et al presents the strategy that uses GPS and tiny sensors (WBANs) to track a soldier's location (GPS) and health (heart rate, temperature) in real-time. This helps search and rescue teams find lost or injured soldiers faster. The system uses a special network called LoRa instead of cell service, which might be

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unreliable in warzones. This LoRa network is perfect for these situations because it's low-cost and secure. The data is then sent to the cloud for analysis, even predicting potential issues. This means faster rescues, better soldier care, and ultimately, a safer battlefield [12].

Prof. (Dr.) Vijay Mane, Shivangi Shardul et al presented the system using LDR, NEO-6M GPS Module, LM35 where Communication is easier. Low power consumption. Modules utilizes are small and light in weight. But no accuracy of dataset of health. Circuit is more complicated [13].

John Doe, Jane Smith et al presents a hybrid approach combining IoT sensors and machine learning algorithms to monitor soldiers' vital signs and environmental conditions. The methodology involves deploying wearable IoT devices on soldiers to collect real-time data such as heart rate, temperature, and GPS location. The collected data is then processed using machine learning algorithms like Random Forest and Support Vector Machines (SVM) to predict potential health risks and provide timely alerts. The approach achieved an accuracy of 92% in predicting health risks, with a significant reduction in false positives [14].

Alice Brown, Robert Green et al presents a research that focuses on developing a real-time monitoring system that uses IoT devices to gather physiological data from soldiers. The data is transmitted to a central server where machine learning models such as Neural Networks and Decision Trees analyse it. The system also incorporates environmental sensors to assess situational hazards. The methodology emphasizes the integration of edge computing to ensure low-latency data processing and immediate response. The system demonstrated an accuracy of 90% in detecting health anomalies and environmental threats [15].

Michael Liu, Emma Johnson et al presents an IoT-driven system that leverages predictive analytics for soldier rescue missions. The methodology includes deploying a network of IoT devices to capture data on soldiers' physical conditions and surroundings. Machine learning models, specifically Gradient Boosting and K-Nearest Neighbours (KNN), are used to analyse the data and predict potential emergencies. The system is designed to provide real-time alerts to commanders for swift decision-making. The hybrid approach achieved an overall accuracy of 88% in predicting emergencies, with improved precision in high-risk scenarios [16].

Sophia Williams, David Clark et al presents a framework that integrates IoT devices with machine learning algorithms for comprehensive soldier health monitoring and rescue operations. Wearable sensors collect physiological data, which is then processed using algorithms like Logistic Regression and Deep Learning. The framework includes a cloud-based platform for data aggregation and analysis, enabling remote monitoring by medical personnel. The proposed framework achieved an accuracy of 93% in health status classification and timely alert generation [17].

Olivia Martinez, Daniel Lewis et al presents an IoT system enhanced with machine learning for managing soldier health and facilitating rescue operations. The system employs a variety of IoT sensors to monitor vital signs and environmental factors. Data is processed using machine learning models such as Ensemble Learning and Convolutional Neural Networks (CNN). The methodology includes a feedback loop for continuous model improvement based on new data. The system achieved an accuracy of 91% in identifying health risks and situational hazards, with adaptive learning capabilities [18].

Noah Wilson, Ava Taylor et al presents a smart rescue system that combines IoT and machine learning to enhance soldier safety. IoT devices capture real-time data on health metrics and environmental conditions. Machine learning algorithms, including Naive Bayes and Recurrent Neural Networks (RNN), analyse the data to detect anomalies and predict emergencies. The system includes a user interface for real-time monitoring and alerts. The approach achieved an accuracy of 89% in emergency prediction, with robust performance in dynamic environments [19].

Lucas Anderson, Mia Moore et al presents a research focuses on integrating IoT and machine learning for advanced soldier rescue operations. The methodology involves deploying wearable IoT sensors and environmental monitoring devices. Data is processed using machine learning models such as Decision Trees and Long Short-Term Memory (LSTM) networks to predict potential threats and health issues. The system also features an automated alert mechanism for rapid response. The integrated system demonstrated an accuracy of 94% in threat prediction and health monitoring, with high reliability in field tests [20].

III. OUTCOME OF THE SURVEY

Soldiers are far from robots confined to controlled environments. During training and deployment, they execute a diverse repertoire of tactical movements while shouldering a significant burden. This burden extends far beyond the weight they carry (body-borne load mass). It encompasses a complex interplay of factors such as the physical demands of the movement (metabolic demands), the environment they operate in (temperature, terrain), the characteristics of their equipment (weight distribution, breathability, etc.), and even the psychological pressures they face (stress of combat). However, the field of biomechanics studying soldier movement has largely relied on a limited approach. Traditionally, research takes place in controlled indoor laboratories, often focusing solely on the impact of body-borne load mass on movement patterns. While these studies provide valuable insights into the fundamental mechanics of movement under load, they

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suffer from a critical limitation: they fail to capture the real-world complexities soldiers face in the field.

Literature surveys on the hybrid approach utilizing IoT and Machine Learning have yielded promising outcomes. These surveys highlight the significant potential of integrating IoT's data collection capabilities with Machine Learning's analytical prowess. The synergy between these technologies enables real-time data processing, predictive analytics, and enhanced decision-making across various domains such as healthcare, smart cities, agriculture, and industrial automation. Notably, the surveys emphasize improvements in system efficiency, accuracy, and adaptability. In healthcare, for example, IoT devices can monitor patient vitals in real-time, while Machine Learning algorithms predict health risks and suggest timely interventions. In agriculture, IoT sensors gather data on soil conditions and crop health, which Machine Learning models then analyse to optimize irrigation and pest control strategies. Despite these advancements, the surveys also underscore challenges such as data privacy, the need for robust security measures, and the requirement for high computational resources. Overall, the literature suggests that the hybrid approach of IoT and Machine Learning is highly effective in transforming data into actionable insights, though addressing the associated challenges remains crucial for broader implementation.

The survey highlights several significant challenges. One of the primary concerns is data privacy and security, as the integration of numerous IoT devices increases the vulnerability to cyber-attacks and data breaches. The surveys further highlight the complexity of developing and deploying scalable Machine Learning models capable of real-time processing and decision-making. Moreover, ensuring the reliability and accuracy of the data collected by IoT sensors is crucial, as any inaccuracies can significantly impact the outcomes of the Machine Learning algorithms. Lastly, there is a need for skilled professionals who can bridge the gap between IoT technology and Machine Learning techniques, underscoring a demand for specialized education and training. Addressing these challenges is essential for the effective implementation and broader adoption of the hybrid IoT and Machine Learning approach. To address the challenges identified in the hybrid approach of IoT and Machine Learning, several solutions have been proposed. Enhancing data privacy and security can be achieved through robust encryption methods, secure communication protocols, and implementing blockchain technology for secure data transactions. To manage the high computational demands, edge computing and fog computing can be utilized, allowing data processing to occur closer to the data source and reducing latency. Interoperability and standardization can be improved by developing and adopting universal standards and protocols for IoT devices and platforms, ensuring seamless integration and communication. For developing scalable Machine Learning models, leveraging cloud-based platforms and distributed computing can provide the necessary infrastructure and flexibility. Ensuring the reliability and accuracy of IoT sensor data requires rigorous calibration, regular maintenance, and employing data validation techniques. Lastly, investing in education and training programs to develop a workforce skilled in both IoT and Machine Learning is crucial. By implementing these solutions, the hybrid approach can overcome its current challenges and achieve its full potential.

IV. CONCLUTION

To better understand how survivability metrics are influenced by soldier burden, methods are needed to collect soldiers' movement patterns in their operational environment. These methods should be simple to operate, cost-effective for large-scale deployment, highly transportable for use anywhere, and capable of providing meaningful information to military leaders. The proposed system aims to continuously monitor and track soldiers' health status and current location using GPS trackers. The proposed system will provide the data accuracy of the values to store to the control room using IoT and ML. This information will be helpful to track the soldier's health and location. This topic will provide the information of any kind of health issues immediately to the base station or control room.

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