



TEXAS A&M
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Senior Design Benchmarking
Hemaya: Non-invasive multi-sensor wearable wristband
for fatigue prevention

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“On my honor, as an Aggie, I have neither given nor received unauthorized aid on this academic work.”

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1. Introduction

Rapid advances in technology and construction have resulted in a surge in the building of high-rises, skyscrapers, and bridges globally, escalating the need for construction labor. This swift expansion necessitates meticulous planning, significantly impacting the physical and psychological health of workers. Addressing this issue is essential to preventing serious harm, including fatalities. This project aims to develop a non-invasive multi-sensor wristband called 'Hemaya' that monitors construction workers' oxygen saturation, heart rate, and tremor to detect fatigue and locate them in real-time situation assessment. [1]

Construction workers are exposed to intense physical labor, long working hours, and extreme weather conditions, resulting in high levels of fatigue, a leading cause of accidents and injuries at work despite improvements in safety measures and equipment, fatigue is an ongoing problem. Studies such as "Effect of Heat Stress on Cardiac Mortality in Nepalese Migrant Workers in Qatar" have highlighted the need for ongoing health monitoring due to the association between heat stress and increased worker mortality due to heart disease.[2]

Wearable technology for healthcare has evolved dramatically over the past decade. Research shows that wearable systems can monitor fatigue by tracking medical symptoms consistently and being comfortable over time. Studies such as "Fatigue Monitoring Through Wearables: A State-of-the-Art Review" highlight the critical role fatigue monitoring plays in occupational health and safety. Wearable programs can monitor mental and physical performance affected by fatigue, increased risk of injury, and decreased productivity. However, existing solutions have limitations, such as testing in controlled environments and over short periods of time, limiting their practical application.[3]

To address these challenges, Hemaya uses a multisensory approach to real-time fatigue detection by integrating sensors to monitor oxygen saturation levels, heart rate, and handshaking. This innovative solution aims to increase safety, reduce accidents, and improve the welfare of construction workers, promoting a safer and more efficient working environment.

The proposed wristband overcomes these limitations by integrating multiple sensors to measure oxygen saturation, heart rate, and hand tremor, ensuring a complete physiological evaluation.

Using a machine learning algorithm implemented on Arduino microcontroller will process the data collected by these sensors for real-time fatigue analysis. Collected data can be instantly viewed in the accompanying app, enabling fatigue to be quickly addressed and immediate action taken when needed.

Development includes a broad range of hardware and software components, data processing, analytics, and integration of machine learning. Hardware includes triaxial accelerometer ADXL335 and heart rate monitor pulse oximeter biosensor MAX30102, which connects the Arduino Uno Rev4 microcontroller. Software programmed through Arduino IDE will optimize sensor performance and monitor power consumption. The data collected by the sensors will be processed and analyzed, with real-time data transfer enabled by the Arduino Uno R4 Wi-Fi module.[4]

The project addresses a number of challenges, such as severe weather in Qatar, connectivity issues, delayed Institutional Review Board (IRB) approvals, and battery life optimization.

2. Existing Solutions

An abundance of commercial health-tracking wearable gadgets have been developed in response to the rising concern for general health. These devices are designed to measure health and fitness. Now available on the market are fitness bands and smartwatches that are able to monitor vital signs related to health. On the other hand, the construction workers that we intend to assist frequently do not have access to this equipment, mostly because of the expensive cost of these appliances. These devices are expensive because they have features like stylish designs, attractive aesthetics, and compact form factors. All of these aspects require substantial engineering, which drives up the expense of maintaining these devices.

Furthermore, in order to communicate data in real time, the majority of these items require a nearby smartphone. If they do not have a smartphone, they will have to wait to reconnect, which is counterproductive to our objective of real-time health tracking. Even while some of these devices do feature artificial intelligence algorithms that can determine the level of fatigue

experienced by a worker, they are still out of reach for the demographic that we are trying to reach. Through the implementation of our project ‘Hemaya’, we intend to close this gap by providing a solution that is not only economical but also capable of detecting oxygen saturation, heart rate, and tremor in real time. This will make the solution accessible and practical for construction workers.

2.1 OURA Ring Generation 3

The Oura Ring Generation 3 is a smart wearable device designed to track various aspects of health and fitness, offering several advanced features. It provides comprehensive health tracking, including sleep monitoring (tracking deep, light, and REM sleep stages and providing a sleep score), activity tracking (monitoring daily activities, steps, and calories burned), and a readiness score that combines sleep, activity, and other metrics to indicate overall readiness for the day. The ring is equipped with advanced sensors for continuous heart rate monitoring, including resting heart rate and heart rate variability (HRV), as well as body temperature sensing to measure deviations and provide insights into health and recovery. [5]



Figure 1: Picture of Oura Ring Generation 3 [6]

2.2 Apple Watch Series 9

The Apple Watch Series 9 is a feature-rich smartwatch that offers a range of advanced functionalities to enhance health, fitness, and daily convenience. It includes comprehensive health monitoring capabilities such as heart rate tracking, ECG, blood oxygen measurement, and sleep tracking. The Series 9 introduces a more powerful S9 chip, ensuring smoother performance and longer battery life. It is also equipped with improved fitness tracking, including advanced workout metrics and personalized coaching. Additionally, the Apple Watch Series 9 provides robust connectivity options, such as cellular support, allowing users to stay connected even without their iPhones. The design remains sleek and customizable, with various bands and watch faces to suit individual styles. [7]



Figure 2: Picture of Apple Watch Series 9 [7]

2.3 Whoop 4.0

The WHOOP wearable is a tech fitness and wellness tracker created for athletes and health enthusiasts, providing a variety of functions. It constantly monitors heart rate and heart rate variability (HRV). Sleep patterns offer in depth insights into the users well being and fitness. With the WHOOP, users receive a recovery score based on sleep quality, intensity of activity and other factors to assist them in optimizing their training regimen and recovery process. Its strain coach feature offers guidance on maintaining exertion levels for peak performance while

avoiding overtraining. The device also keeps tabs on rate and skin temperature to detect signs of potential illness or fatigue. Moreover, the WHOOP boasts a design for comfort and durability, along with a long battery life and automatic data synchronization, for hassle free continuous usage. The accompanying app provides analytics, personalized recommendations, and community support features to help users reach their health and fitness objectives effectively [8].



Figure 3: Picture of WHOOP watch [8]

2.4 Samsung's Galaxy Watch 5 Pro

The Samsung Galaxy Watch 5 Pro is a smartwatch made with a titanium case and a sapphire crystal display. It includes in-depth health tracking such as heart rate monitoring, ECG readings, and blood oxygen levels, along with sleep tracking and body composition measurements. The watch is equipped with GPS, route mapping, and various outdoor workout modes, delivering battery life and efficient performance while running Wear OS. It seamlessly connects to the Samsung ecosystem for receiving notifications, controlling home devices, and using Samsung Pay. Additionally, it offers personalized watch faces and interchangeable bands for customization [9].



Figure 4: Picture of Samsung Galaxy Watch 5 Pro [10]

3. Benchmarking Criteria

This section provides an overview of the main standards used to evaluate the ‘Hemaya’ project, which is a wristband equipped with multiple sensors that is aimed to identify fatigue in construction workers without the need for invasive methods. The benchmarking criteria cover a range of factors, such as public health, environmental effect, social and global impact, economic impact, welfare, cultural impact, and safety. Every criterion assesses the project's potential advantages and difficulties, guaranteeing a thorough evaluation of its efficacy and practicability in improving worker safety and well-being.

The ‘Hemaya’ project criteria emphasize the integration of advanced features to enhance worker safety. The system employs Wi-Fi and Bluetooth for smooth and uninterrupted connection, while relying on cloud storage for safe and secure data management. The device incorporates the monitoring of heart rate and SpO2 levels, together with the detection of tremors, in order to offer a thorough understanding of one's health. The device has a charging duration of 4-6 hours, ensuring minimal downtime. The device is mobile app compatible, enables IoT for improved functionality, and is compatible with various operating systems such as Apple iOS, Android, and web platforms, enabling widespread accessibility and usage.

3.1 Safety

Enhancing safety for construction workers is the primary objective of the ‘Hemaya’ project, which involves providing real-time fatigue monitoring. By detecting fatigue early, the wristband contributes to accident and injury prevention, thus promoting a safer working environment. Expert feedback emphasizes the crucial role of fatigue management in maintaining worker safety, further reinforcing the focus on safety. The ‘Hemaya’ wristband sets a new standard in occupational safety by showcasing the effectiveness of advanced health monitoring technologies in protecting workers.

3.2 Welfare

Continuous health monitoring, as implemented in the ‘Hemaya’ project, plays a crucial role in enhancing worker welfare. By actively monitoring the health of workers, this initiative aims to minimize workplace injuries and promote overall improvement in worker health. Comprehensive support for basic human needs is in line with the efforts of governments and organizations. The project aims to create a work environment that prioritizes worker safety and health, ultimately improving the overall quality of life for construction workers.

3.3 Public Health

The ‘Hemaya’ project aims to enhance public health by providing construction workers with a wristband that monitors vital indicators, including oxygen saturation, heart rate, and tremor. The device enhances the capability of preventing health-related issues, prolonging life, and promoting overall well-being through timely interventions by offering real-time fatigue detection. By adopting a proactive approach to health monitoring, workplace accidents and injuries can be significantly reduced, leading to a healthier workforce.

3.4 Social and global impact

The potential of the ‘Hemaya’ wristband to improve the health and safety of construction workers can create a significant social and global impact. Promoting a culture of proactive health management is achieved by raising awareness about the importance of health monitoring. Better

working conditions and global inspiration can be achieved through the implementation of this technology. Furthermore, the importance of implementing enhanced safety measures is highlighted, urging industries across the globe to embrace more efficient health monitoring systems.

3.5 Cultural Impact

The potential of the ‘Hemaya’ Project to transform attitudes towards worker health and safety in the construction industry is significant in terms of its cultural impact. The project aims to foster a culture of safety and proactive health management by incorporating innovative health monitoring technology. These changes in culture can result in improved health practices, increased awareness, and a greater focus on safety standards, not just in Qatar but also in the construction industry worldwide. The project highlights the significance of worker health, promoting a more dedicated and compassionate approach to workplace safety.

3.6 Economic Impact

In terms of cost, the ‘Hemaya’ wristband offers an affordable solution for monitoring the health of construction workers. The wristband has the potential to generate significant savings in healthcare and accident-related costs by minimizing the need for frequent medical check-ups and reducing the risk of fatigue-related accidents. Long-term economic benefits can help offset the initial investment in these devices. These benefits include lower healthcare expenses and increased worker productivity. This economic advantage makes the project attractive to employers and stakeholders in the construction industry.

4. Benchmarking Table

Table 1 below compares our prototype to the existing solutions in the market discussed in Section 2.

Features	Hemaya (Our product)	Whoop 4.0 [11],[12],[13]	OURA Ring Generation 3 [14],[15],[16]	Apple Watch Series 9 [17]	Samsung's Galaxy Watch 5 Pro [18], [19], [20]
					
Cost	\$99.95	\$239.00 + renew subscription \$30/month.	\$299.00	\$399.00	\$499.00
Wi-Fi	Yes	No	No	Yes	Yes
Cellular	No	No	No	Yes	Yes
Bluetooth	Yes	Yes	Yes	Yes	Yes
Cloud Storage	Yes	Yes	Yes	Yes	Yes
Battery Life	We don't have an information	5 Days	4-7 days	18 hours	3 days
Charging time	4-6 hours	2 hours	20-80 minutes	Up to 80% charge in about 45 minutes	2 hours
Product Weight	Approximately 0.301 kg	0.25 Pounds / 0.11 kg	4 - 6 grams (depending on ring size)	39.0 grams	46.49 grams

Heart rate and SPO2 Monitor	Yes	Yes	Yes	Yes	Yes
Tremor Monitor	Yes	No	Yes	Yes	Yes
Sleep Tracking	No	Yes	Yes	Yes	Yes
Water Resistance	No	Yes	Yes	Yes	Yes
Mobile App Compatibility	Yes	Yes	Yes	Yes	Yes
IoT Support	Yes	No	Yes	Yes	Yes
Operating System Compatibility	Apple iOS, Android, website	Apple iOS, Android	Apple iOS, Android	Apple iOS	Android
Warranty	We don't have any information	1 year	1 year	1 year	1 year

Table 1: Shows the comparison of the benchmarking wearable devices.

5. Benchmarking Study Analysis and Summary

5.1 Summary of Findings

Based on a thorough analysis of existing market solutions and different criteria, it is clear that our safety wristband offers significant advantages. Our wristband, in contrast to more common consumer goods like the Apple Watch Series 9 or OURA Ring Generation 3, is designed for the difficult conditions and demands of construction work. It guarantees immediate alerts and avoids errors brought on by fatigued workers. Additionally, our product is more cost-effective and promotes the welfare, public health, and safety of construction workers who operate in hazardous conditions. Compared to other products, our wristbands are more affordable.

Furthermore, its ability to function wirelessly by connecting to an app enhances its functionality and ensures continuous monitoring and accurate readings. The OURA Ring Generation 3 is the closest competitor in terms of features. Still, it is much more expensive (from approximately

\$300 up to \$600) than our more affordable safety wristband (approximately \$99.95).

5.2 Changes that will be done to Initial Project Design

Despite our best efforts to create a highly functional and efficient product, it needed certain modifications based on the equipment and tools it was to be used with. The first modification is replacing the existing 3.7-volt battery with a 6-volt rechargeable one. The 6-volt battery will improve our product's overall efficiency and reliability by offering a more steady and long-lasting power source. This modification makes the device more user-friendly and efficient by ensuring it can run for extended periods without frequently needing recharging. In addition, we will purchase a pre-made wristband rather than making a DIY one. This method will save time and money since pre-made wristbands have already been created and may be tested for comfort and durability. We can concentrate our attention on other important product features, including ensuring users receive a comfortable and high-quality wristband. Lastly, we will use the Arduino UNO R4 Wi-Fi instead of the Nano ESP32 since it is incompatible with our sensors and has limited cloud integration. Even though the Nano ESP32 was recommended as it's smaller, the Arduino UNO R4 Wi-Fi provides strong cloud integration capabilities and compatibility with our sensors. With this modification, the development process will go more smoothly, increase data transmission efficiency, and guarantee cloud service connectivity. The Arduino UNO R4 WiFi combines the processing power and exciting new peripherals of the RA4M1 microcontroller from Renesas with the wireless connectivity power of the ESP32-S3 from Espressif. Our solution will thus be more reliable and adaptable, fulfilling the exacting requirements for modern health system functionality.

6. Conclusion

The development of the 'Hemaya' non-invasive multi-sensor wearable wristband represents a significant step forward in improving the safety and well-being of construction workers. Introducing this new device addresses the important issue of fatigue, a major cause of accidents and injuries occurring in the construction industry. It provides comprehensive real-time analysis, enabling immediate intervention when needed. Compared to existing market solutions, Hemaya

stands out due to its unique combination of features, low cost, and user orientation. Although other wearables like the Apple Watch and OURA Ring offer some similar functions, though often come at a higher price and lack specific features manufacturers need in the coatings. It is a valuable tool for promoting public health and safety. In addition, changes to the original design, such as an up long-lasting battery and the use of Arduino UNO R4 Wi-Fi, greatly improve the product's performance reliability and user experience This flexibility ensures that not only 'Hemaya' practical and effective solutions but also ready for practical use in challenging situations.

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