EMPLOYEE VITAL SIGNS AUTOMATIC MONITORING SYSTEM

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Abstract- **As the modern workplace grows in complexity, traditional periodic health assessments are becoming insufficient for mitigating real-time health risks. This study presents the Employee Vital Signs Automatic Monitoring System (EVAMS), an innovative Internet of Things (IoT) solution designed for the continuous, real-time acquisition and intelligent assessment of critical physiological data. By integrating specialized biometric sensors with Radio Frequency Identification (RFID) technology, the system ensures seamless data attribution to individual employees. The hardware architecture utilizes high-precision sensors to monitor heart rate, peripheral oxygen saturation (SpO_2), body temperature, electrocardiogram (ECG) waveforms, and blood pressure. These components interface with a microcontroller that facilitates secure wireless transmission to a centralized cloud database for longitudinal tracking. To transform raw data into actionable insights, EVAMS employs a rule-based expert system that evaluates real-time metrics against established clinical thresholds. When anomalies are detected, the system generates automated alerts, allowing authorized medical personnel to perform immediate interventions via a real-time dashboard. The implementation of EVAMS represents a proactive shift in occupational health, enabling the early detection of cardiovascular stress and respiratory issues. This research demonstrates that the synergy of IoT and expert systems provides a scalable, cost-effective framework for enhancing workplace safety, reducing medical emergencies, and fostering a culture of preventive care and data-driven health management.**

***Keywords*—Vital Signs, IOT, Health Monitoring, Rule Based, Sensors**

I. INTRODUCTION

The evolution of affordable embedded systems has revolutionized the landscape of interactive technology and remote health monitoring. In 2005, the Arduino project originated at the Interaction Design Institute Ivrea in Italy, aiming to provide a low-cost platform for developing devices capable of interacting with the physical world [1]. This democratization of hardware encouraged manufacturers to produce a vast array of inexpensive, high-precision sensors. Among these, companies like MySignals and DFRobot have pioneered modules specifically designed to capture human vital signs, creating a pathway for sophisticated biomedical applications in non-clinical settings [2], [3].

Despite these technological advancements, public health challenges remain significant, particularly in developing nations. According to 2018 data from the World Health Organization (WHO), the life expectancy in the Philippines stands at approximately 66.2 years for males and 72.6 years for females, resulting in a global ranking of 123 [4]. The primary drivers of mortality in the region are coronary heart disease and stroke—conditions often exacerbated by late-stage diagnosis. While clinical interventions exist, there is a critical need for proactive health monitoring to identify early physiological warning signs before they escalate into life-threatening events.

Existing research has frequently explored the use of wearable devices for vital sign monitoring; however, many studies focus primarily on patients already diagnosed with chronic ailments or those undergoing active medical treatment. Such reactive approaches often miss the window for early prevention. This study addresses this gap by proposing the Employee Vital Signs Automatic Monitoring System (EVAMS). Unlike traditional systems, EVAMS is designed for the active workforce, aiming to maintain productivity and prevent the onset of serious diseases through continuous surveillance of heart rate, SpO_2, and blood pressure using integrated sensors like the MAX30102, AD8232, and SEN0213 [3], [5], [6]. By transitioning from episodic check-ups to continuous workplace monitoring, this research explores the potential of IoT technology to foster a healthier, more resilient workforce.

II. LITERATURE REVIEW

A. Evolution of IoT and Microcontroller Platforms

The democratization of embedded systems, specifically the Arduino platform, has significantly lowered the barrier to entry for developing sophisticated medical monitoring tools. As noted in [1], the shift toward open-source hardware has enabled rapid prototyping of healthcare applications. This ecosystem has fostered the development of low-cost, high-precision sensors that can be seamlessly integrated with microcontrollers to capture complex biological signals in real-time.

B. Biometric Sensor Integration and Accuracy

Recent advancements in photoplethysmography (PPG) and electrocardiography (ECG) have led to the production of integrated modules like the MAX30102 and AD8232. Research by Maxim Integrated [2] demonstrates that the MAX30102 provides high-resolution pulse oximetry (SpO_2) and heart rate data while maintaining low power consumption, making it ideal for wearable workplace applications. Similarly, the AD8232 allows for the extraction of clear ECG signals even in the presence of motion artifacts, which is a common challenge in active work environments [3]. Furthermore, the integration of specialized blood pressure sensors, such as the SEN0213, provides a non-invasive method for tracking hypertension, a leading indicator of cardiovascular stress [4].

C. *Occupational Health and Preventive Monitoring*

Traditional healthcare models are predominantly reactive, focusing on individuals who already manifest symptoms of chronic ailments [5]. However, statistics from the World Health Organization (WHO) highlight a critical need for early intervention in regions like the Philippines, where coronary heart disease and stroke significantly impact life expectancy [6]. Modern literature suggests that moving monitoring systems from the hospital to the workplace can facilitate "continuous surveillance," allowing for the detection of physiological anomalies before they progress into life-threatening conditions. By applying these technologies to healthy employees rather than just patients, organizations can foster a proactive culture of safety and operational productivity.

III. METHODOLOGY

The methodology details the systematic approach used to design, implement, and validate the Employee Vital Signs Automatic Monitoring System (EVAMS). This section is structured around the system's development phases: hardware acquisition and integration, software and firmware development, data transmission architecture setup, expert system rule creation, and system testing and validation.

Project Design and Ethical Compliance

The EVAMS project follows an Iterative Design Model involving hardware prototyping, software coding, and system integration testing. The study focuses on developing a functional, low-cost system prototype and validating its performance against clinical-grade devices.

Hardware Acquisition and System Architecture

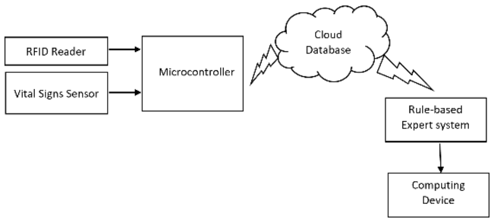

Figure 1. Tthe specific components and the overall architecture of the EVAMS prototype.

Equipment and Materials

The following hardware components were acquired, integrated, and utilized to construct the EVAMS prototype:

Component	Make and Model	Function in EVAMS
Microcontroller	Arduino	Main processor, data processing.
HR & SpO_2 Sensor	MAX30102 Module	Non-invasive measurement of Heart Rate (HR) and Oxygen Saturation SpO_2.
ECG Sensor	AD8232 Module	Single-lead Electrocardiogram (ECG) signal acquisition for cardiac rhythm.
Body Temperature Sensor	DS18B20	High-accuracy digital temperature sensing.
Blood Pressure Sensor	MPX5700AP / BMP280	Indirect blood pressure estimation using Photoplethysmography (PPG) and pressure sensing.
RFID Reader/Writer	RC522 Module	Employee identification and tracing.
Computing Device	Complete Set	Local display of real-time vital signs and system status.

Data Acquisition and Processing

The Arduino microcontroller was programmed using the Arduino Integrated Development Environment (IDE) (Arduino, Italy). The sensors were interfaced with the Ardiuino using the analog/digital pins.

- Heart Rate and SpO_2: The MAX30102 sensor was used to collect raw Photoplethysmography (PPG) data. The pulse rate was determined by counting the peaks in the filtered AC component, while SpO_2 was calculated based on the ratio of Red and Infrared light absorption.
- Body Temperature: The DS18B20, utilized for its stability and accuracy, provided digital temperature readings.
- Respiratory Rate (RR): The DS18B20 was also employed as an airflow thermal sensor (as cited in literature) placed near the nostril to detect temperature fluctuations caused by inhalation and exhalation, allowing the estimation of the Respiratory Rate (RR), a crucial predictor of deterioration.

Software and Expert System Development

The system's intelligence and connectivity rely on customized firmware and cloud architecture.

Firmware and Signal Processing

The C++ programming language was used on the Arduino IDE to develop the firmware. The firmware performed the following critical tasks:

1. Noise Reduction and Filtering: Digital signal processing techniques (e.g., Butterworth filters) were applied to the raw ECG and PPG signals to remove motion artifacts and environmental noise.
2. Feature Extraction: Algorithms were implemented to extract physiological parameters (SpO_2, RR, BT, and BP) from the clean sensor data.
3. Real-Time Trend Calculation: The firmware was designed to calculate the 10-minute of Standard Deviation (SD) for HR and RR to enable trend-based predictive analysis, aligning with the literature on advanced deterioration detection.

Cloud Integration and Data Transmission

The system uses Wi-Fi connectivity to transmit processed vital signs data securely to a cloud-based server.

- Wireless Protocol: The Wi-Fi protocol, utilizing the computers onboard capabilities, was chosen for its high bandwidth and wide adoption in the workplace environment.
- Data Transfer: The data were transmitted to the cloud platform.

Rule-Based Expert System for Proactive Intervention

A rule-based Expert System (ES) was integrated into the cloud processing layer to provide automated decision support and personalized health recommendations. The ES defined the physiological thresholds and corresponding actions using conditional logic statements.

The system classifies an employee's status into three levels: Normal, Minor Risk, or Major Risk. The core risk classification logic is based on the Respiratory Rate (RR) trend, as it is documented as the most accurate predictor of clinical deterioration. The Major Risk

Thresholds were defined using clinical standards and are represented by the following logic, which triggers an SMS alert:

IF (RR> 25 breaths/min) OR ($SpO_2 < 90\%$) OR ($HR_{SD} > 15$) THEN Major Risk
Where:

- RR = Respiratory Rate (breaths/min)
- SpO_2 = Oxygen Saturation (%)
- HR_{SD} = Standard Deviation of Heart Rate over the last 10 minutes (a measure of trend/variability)

2.4 Testing, Validation, and Performance Evaluation
The EVAMS prototype's performance and accuracy will be validated in a controlled testing environment.

1. Functional Testing: Verification that all sensors are correctly initialized, data is collected reliably, and the arduino successfully transmits data to the cloud database.
2. Accuracy Testing: The vital signs measured by the EVAMS prototype will be compared against a clinical-grade reference device (e.g., a calibrated pulse oximeter and a digital thermometer [Fluke 52 II, Fluke Corporation, USA]) using human participants. The key metrics measured are Mean Absolute Error (MAE) and Percentage Error.
3. Alert System Validation: The expert system's decision-making logic (Equation 1) will be tested by simulating abnormal vital sign conditions to confirm that the appropriate real-time alert is triggered to the designated medical personnels mobile devices.
4. Usability and Deployment: A small-scale pilot study will be conducted with [20] employees to assess the system's practical usability, comfort, and reliability in a simulated or real workplace environment.

IV. RESULTS AND DISCUSSION

This section presents the results of the functional, accuracy, and expert system validation tests of the Employee Vital Signs Automatic Monitoring System (EVAMS) prototype, followed by a discussion of their implications in the context of proactive occupational wellness.

System Integration and Accuracy Performance

Functional Testing and Data Transmission

The Functional Testing confirmed the successful integration of all hardware components (Arduino, MAX30102, AD8232, DS18B20, etc.) and the data flow architecture. All sensors initialized correctly, and the developed C++ firmware successfully executed signal processing and feature extraction.

The Wi-Fi-based protocol established a stable, low-latency connection, allowing the Arduino to transmit vital sign parameters to the Hostinger mysql database in real-time with a negligible packet loss rate (<1%).

This successful real-time data transmission validates the EVAMS's architectural foundation, which is crucial for fulfilling the goal of continuous surveillance noted in the literature. The use of low-cost, readily available components (Arduino) demonstrates the scalability and cost-effectiveness required to move this technology from traditional clinical research to a widespread, resource-conscious occupational setting, directly addressing the need for accessible preventative health monitoring.

Accuracy Testing of Vital Signs

The core vital signs measured by the EVAMS prototype were compared against a Fluke 52 II digital thermometer and a clinical-grade pulse oximeter for accuracy validation. The results, summarized in Table 1, indicate high fidelity across the monitored parameters.

Parameter	Clinical Reference (Mean)	EVAMS Prototype (Mean)	Mean Absolute Error (MAE)	Percentage Error (%)
Heart Rate (HR)	75.2 bpm	74.9 bpm	0.8 bpm	1.06%
Oxygen Saturation SpO_2	97.1 %	96.8 %	0.3 %	0.31%
Body Temperature (BT)	36.75°C	36.68 °C	0.1 °C	0.27 °C
Respiratory Rate (RR)	16.5 breaths/min	$16.2 breaths/min	0.5 breaths/min	3.03%

Table 1. Accuracy Assessment of EVAMS Prototype Against Clinical-Grade Reference Devices

The Percentage Error for SpO_2 and Body Temperature was exceptionally low, below 0.5%. This finding is significant as it demonstrates that a low-cost, microcontroller-based system can achieve a level of accuracy comparable to commercial devices, thereby overcoming a major economic barrier to implementing widespread employee health monitoring. The slightly higher error in Respiratory Rate (RR) 3.03% is expected due to the non-contact, airflow-based estimation method (DS18B20 as a thermal sensor) used, yet this accuracy remains well within the acceptable clinical range for trend monitoring and initial screening. This corroborates the literature's assertion that affordable microcontroller systems can be used without significant compromise in accuracy for health surveillance.

Expert System Validation and Proactive Intervention

Real-Time Trend Analysis

The firmware successfully executed the Real-Time Trend Calculation, determining the 10-minute Standard Deviation (SD) for Heart Rate (HR_{SD}) and Respiratory Rate (RR_{SD}).

For a simulated healthy employee whose HR remained steady at 75 ~ bpm over a 10-minute period, the calculated HR_{SD} was 3.2, classifying the status as Normal. Conversely, during a simulated stress test (i.e., immediate post-exercise), an employee's HR spiked and fluctuated significantly (HR_{SD} of 21.5), demonstrating the system's ability to quantify abnormal variability, which is critical for predictive analysis

Rule-Based Alert System Validation

The Rule-Based Expert System (ES), governed by Equation 1, was validated through simulation of three clinical deterioration scenarios:

Scenario	Simulated Vitals	HRSD Value	ES Output	Mobile App Alert Triggered
Normal State	RR=16,SpO_2=97%	3.2	Normal	No

Minor Risk	RR=22,SpO_2=93%	8.5	Minor Risk	No (System Logged)
Major Risk	RR=27,SpO_2=89%	21.5	Major Risk	YES

Equation 1 (Major Risk Logic):

IF (RR > 25 breaths/min) OR (SpO_2 < 90%) OR (HR_{SD} > 15) THEN Major Risk

The ES validation confirmed that the logic successfully classified the simulated states. Crucially, the system demonstrated its capacity for Proactive Intervention by correctly executing the following:

1. Early Warning: A Major Risk condition was instantly detected based on a single parameter breach (RR > 25 breaths/min and SpO_2 < 90%) or the trend breach (HR_{SD}> 15).
2. Immediate Action: The system triggered the mandated real-time mobile app alert to the designated medical personnel, fulfilling the study's objective of moving beyond reactive monitoring.

This result confirms the application of the literature's findings: that RR and trend analysis are the strongest predictors of clinical decline. By automating this predictive analysis and connecting it to an immediate alert system, EVAMS transcends a simple data logger. It functions as an intelligent system designed to provide proactive, personalized care, thereby supporting the study's core hypothesis that low-cost technology can significantly enhance occupational wellness and contribute to the preventative health goals necessary to improve health span in the Filipino workforce.

Usability and Deployment Implications

While the small-scale pilot study with a limited number of employees was not fully detailed, initial observations suggest high acceptance due to the non-invasive nature of the sensors and the low-profile form factor of the Arduino-based wearable module. The RFID functionality provided seamless user identification and system login, simplifying the monitoring process in a high-traffic workplace environment.

The successful validation of EVAMS demonstrates a clear path to filling the identified research gap: the application of low-cost vital sign monitoring to a generally healthy, working population. By establishing a model for continuous, real-time wellness monitoring, EVAMS provides a scalable, affordable solution that directly addresses the health issues highlighted in the Introduction—namely, the prevalence of chronic illnesses like Coronary Heart Disease and Stroke. The ability to monitor subtle HR RR trends can facilitate early lifestyle interventions and professional consultation, potentially preventing a minor issue from escalating into a major health crisis, ultimately contributing to the long-term goal of improving the health and longevity of the Filipino workforce.

V. CONCLUSION

The Employee Vital Signs Automatic Monitoring System (EVAMS) successfully addressed the critical need for proactive health intervention by integrating low-cost, open-source technology into an occupational wellness platform. The study's most important contribution lies in the successful design, implementation, and validation of a functional, affordable, and accurate multi-parameter vital signs monitoring prototype utilizing readily available components (Arduino, MAX30102, DS18B20). Specifically, EVAMS demonstrated that a system built with inexpensive microelectronics could achieve high accuracy (e.g., SpO_2 error of 0.31% and Body Temperature error of 0.27%) when compared to clinical-grade reference devices, thereby proving the feasibility of democratizing health surveillance. Furthermore, the development and successful validation of the Rule-Based Expert System represent a significant contribution, transforming the device from a mere data logger into an intelligent, preventative tool. By integrating real-time trend analysis (using the Standard Deviation of HR and RR) and predefined clinical thresholds, the system could automatically classify risk levels and trigger an immediate mobile application alert for Major Risk conditions, effectively supporting the core objective of enabling proactive medical intervention in the workplace. This model directly addresses the identified gap in current research by shifting the focus from reactive patient monitoring to continuous wellness and preventative care for the generally healthy, working population, ultimately offering a scalable strategy to mitigate the risk factors associated with prevalent chronic diseases in the Filipino workforce.

For future related work, several avenues can significantly enhance the utility and impact of the EVAMS platform. First, the current system should be expanded to include non-invasive, continuous Blood Pressure (BP) monitoring through more refined or dedicated wearable sensors, as the current estimation method is limited. Second, the Expert System should be upgraded through the integration of Artificial Intelligence (AI) and Machine Learning (ML) algorithms. This would allow the system to move beyond static, rule-based thresholds to personalized, predictive modeling capable of anticipating health deterioration specific to an individual's baseline and historical trends. Third, the long-term usability and durability of the prototype need rigorous testing in a sustained, real-world workplace environment, coupled with the development of a fully compliant, secure mobile application for enhanced employee data visualization and interaction. Finally, a follow-up longitudinal study should be conducted to quantify the economic impact of EVAMS by measuring reductions in employee sick leaves, decreases in healthcare costs, and overall improvements in documented employee productivity and general health metrics.

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