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Arduino-Based Electromyography System for Enhanced Monitoring and Optimisation of Oil Palm Harvesting Manual Workers

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Abstract

Significant changes have been made in the harvesting operations implemented within the oil palm industry. Mechanisation has replaced conventional manual harvesting methods, which are physically intensive work, leading to increased effectiveness. However, despite the known association of manual labour with musculoskeletal problems among workers, it remains crucial in harvesting operations. Electromyography (EMG) has emerged as an essential tool for monitoring muscle activities. This paper aimed to develop an Arduino-based EMG system for muscle activity monitoring in oil palm harvesters as a cost-effective and user-friendly method. The results showed that there was a direct correlation between recorded values and lifted loads, whereby 8kg had the highest reading while 2kg had the lowest reading. It reflects some positive trends in mean values in the weight categories found in the dataset, specifically 0.4238 for 2kg, 0.5078 for 4kg, and 0.7937 for 8kg. Similarly, standard deviations showed an increasing pattern with an increase in weight, indicating a trend for more variation at higher weights. The prototype demonstrated promising results regarding capturing muscle activities under various scenarios, which indicate its potential to assist in designing and developing ergonomically improved machines. Further research needs to be conducted to test the accuracy.

Keywords: Arduino; Electromyography; Harvesting; Muscle activity; Oil palm

1. Introduction

Harvesting is a main activity in the oil palm sector. Obtaining palm fruits at the right ripeness level is of the utmost importance for obtaining the best yield and the best quality of palm oil [1]. Thus, implementing an appropriate harvesting technique is requisite to controlling productivity, decreasing the total amount of produced palm waste, and promoting sustainability in the oil palm industry [2]. Nonetheless, workers use machines or traditional hand tools to pull ripe fruits from the oil palm trees.

Manual labour is at the core of palm oil harvesting activities. Workers engage in extensive labor to harvest crops in addition to their knowledge [3]. Workers mostly use upper-limb muscles throughout the eight-hour harvesting activities, particularly hand muscles, which reduces labour productivity [4].

Electromyography (EMG) is an essential tool for the regulation of various physiological functions—EMG-based monitoring of a wide range of emotions, from stress to pain [5], [6]. EMG's progress successfully deepens researchers' and healthcare specialists' knowledge of how the neuromuscular system works [7]. The EMG data reflecting muscle contractions have also become an appealing method for assessing human muscle activity [8].

Works have shown EMG signals can be used for diagnosing neuromuscular disorders, analysing muscle architecture, and investigating central strategies for motor control [9]. In different scenarios, data collected by EMG, such as contractions of normal muscle, are detrimental in identifying muscle fatigue in clinical settings [10]. Multiple classification methods, such as Artificial Neural Networks (ANN) and Support Vector Machines (SVM), have shown remarkable performance for various EMG uses since straightforward classifications are usually better [11]. Research shows EMG signals to be essential in diagnosing neuromuscular conditions [9].

Integrating Arduino-based EMG systems with Bluetooth capabilities in EMG devices enabled users to wirelessly transmit and access health data, facilitating remote monitoring and analysis [12]. Arduino can be implemented to build interactive objects, which can utilize data from several switches or sensors and may, in turn, manage a selection of lights, motors, or other realizable outputs [13]. An Arduino is a single-board computer with excellent computing power, is very simple to programme, and is anything that an electronic circuit can design with comparatively little effort [14]. This advancement allows for convenient and continuous monitoring of muscle activities, which is particularly advantageous for applications such as monitoring sports performance, aiding rehabilitation, and managing long-term health objectives.

Arduino-based EMG systems are recognised for their cost-effectiveness, offering a more economical means to measure and record muscle activities through EMG technology. These systems have gained popularity among hobbyists, researchers, and students due to their affordability and accessibility [15]. With the help of the Arduino platforms, people can create personalized EMGs that suit their particular needs, which upholds the advantage of this system over traditional high-priced EMG devices [16].

Works show that such systems based on Arduino boards outperform similar devices. One possible context is provided by [17], who developed an economical and convenient Arduino-based, myoelectric control system using wearable EMG sensors that showed promise for a more affordable EMG solution. Furthermore, in a pilot work, [18] was able to verify the use of an EMG system that was low-cost. The result also indicates that even costly EMG setups can be used effectively. In addition, the work of [19] illustrated the potential of Arduino to be used in EMG processing and pattern recognition, which are essential for both basic and advanced prostheses.

The design and implementation of a portable and user-friendly EMG monitoring system using Arduino technology will eliminate the limitations of existing monitoring devices by providing a cost-efficient solution that maintains the accuracy and reliability of signal acquisition [15]. EMG equipment can assist researchers and designers in developing more efficient and ergonomic harvesting equipment. This paper aims to create an Arduino-based EMG system to monitor muscle activities in harvesters in the oil palm sector. The process involved designing and developing the system and conducting functional tests in the laboratory.

2. Material and Methods

Design began with selecting suitable sensors for EMG and ECG signal acquisition, ensuring high fidelity and reliability. The chosen sensors were interfaced with Arduino microcontrollers to facilitate signal processing and conditioning. The EMG sensor was positioned strategically to capture muscle activities. The integration of Bluetooth modules enables wireless communication, allowing seamless connectivity with external devices.

The software development phase involved creating a user-friendly data visualisation and interaction interface. A custom Arduino sketch was developed to manage data acquisition, processing, and transmission over the Bluetooth connection. Signal processing algorithms were implemented to filter and preprocess the raw EMG signals. The system's performance was evaluated through functional testing, where a complete lifting cycle for variable loads involved grasping a load, lifting the load, pausing briefly, lowering the load to the initial position, and then returning to the original lifting position. This step was repeated thrice with a 5-minute break between each repetition. Data collected was anticipated to differ when different loads were applied.

3. Results

3.1. Development of prototype

The development process involved integrating surface EMG sensors with Arduino microcontrollers and Bluetooth modules to create a wearable and nonintrusive monitoring system. The sensors captured electrical signals generated by muscles, and the Arduino platform processed and analyzed these signals in real-time. The system incorporated advanced signal processing algorithms to filter noise, extract relevant features, and transmit the data wirelessly to a computer. Bluetooth connectivity enabled wireless data transmission to a paired device within a 10-meter range, allowing for remote monitoring and control.

The setup comprised an Advanced Technologies Muscle Sensor V3.0 connected to an Arduino Uno ATMega 328p board from Arduino using two separate wires (refer to Fig. 1). A ground wire established the connection between the module’s ground potential and the microcontroller’s ground for grounding purposes. Another wire connected the SIG output, which represents the unprocessed signal, to the analogue input on pin 15 of the microcontroller. A Vs. wire facilitated power transmission from the battery to the module for power supply.

The prototype utilized Arduino Uno as the main base and was equipped with a Bluetooth module with the series number HC-05. HC-05 and HC-06 are two standard Bluetooth modules used with Arduino. The HC-05 module offers a more extended Bluetooth range than the HC-06, rendering it more suitable for applications requiring extended Bluetooth connectivity [20]. The HC-05 module can also function as a master or slave device, providing greater flexibility in various communication requirements [21. On the other hand, the HC-06 module is limited to being used only as a slave device [22].

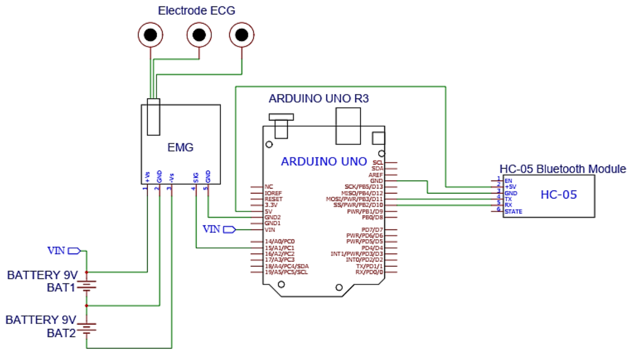

Figure 1. Diagram of Arduino Base EMG

Fig. 2 shows the complete prototype with a casing for board protection and functionality during measurements. The system was equipped with rechargeable batteries for portability. Table 1 depicts the prototype's specifications.

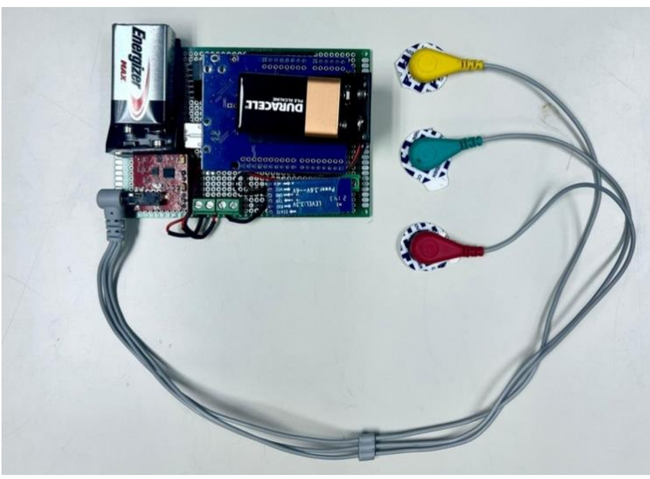

Figure 2. Arduino Base EMG Prototype

Table 1. Specifications of Prototype

Technical Specification	Description
Size	140mm(L) x 90mm(w) x 40mm(H)
Weight	325g
Bluetooth Module	HC-05
Arduino Type	Arduino uno ATMega 328p
Max Distance Data Transmission	10 meters
Speed Data Transmission	Asynchronous:2.1Mbps (Max) / 160 kbps, Synchronous: 1Mbps/1Mbps.

3.2. Functional Test and Validation

A functional test was carried out in the MPOB Electronic Lab located in Bangi Lama. The testing of the Arduino-based EMG device concentrated on hardware components and software algorithms, specifically covering signal acquisition, processing, and output. The work was crucial as it focused on integrating EMG sensors and Bluetooth modules with Arduino technology and computers. The experiment involved three weights to investigate their effect on the EMG readings. The data collection started with a 2kg weight, with each subsequent weight double the previous one, up to a maximum of 8kg.

Electromyographic signals were recorded to quantify the muscle activity. Fig. 3 shows the placement of electrodes or probes on the user's biceps. The position of the electrode or probe was determined based on the muscles that exhibited greater dominance in movement during the test. The electrodes were placed on the biceps muscle. The orientation was adjusted to align with the muscle fibres. Reference electrodes were also used, positioned on a bony area of the hand to reduce interference for accurate EMG measurements (Fig. 3). Results from the work are depicted in Fig. 4.

Figure 3. Position of Electrode at Bicep during measurement

The acquired EMG signals were stored in Excel for offline analysis. Signal acquisition is performed for 10 seconds of each movement at a sampling rate 0.1kHz. Each recording contained 100 samples to ensure accurate data processing.

The tests conducted on a prototype showed a direct correlation between the recorded values and the weight of loads lifted. The peak value was noted when lifting an 8kg load, while the lowest was recorded with a 2kg load. This variation was attributed to the increased muscle engagement required for heavier loads, indicating the prototype's effectiveness. These initial findings highlight the need for further empirical investigations to confirm the collected data and thoroughly assess the prototype's performance. The paper by [22] mentions the responses of the lower limb to load-carrying in walking individuals, supporting the idea that muscle engagement varies with load weight. By applying data processing methodologies and bearing a comparative analysis structure from the work on apple harvesting conducted by [23], future research could enhance their work's precision and have a broader viewpoint of evaluating muscle activities in oil palm harvesters. These improvements help increase the reliability of the EMG monitoring system and, in the future, design and development of harvesting equipment that is more ergonomically friendly to the workers and steadily makes the industry better for everyone in the long run.

In light of these findings, it is essential to recognise that these numerical values indicate the prototype's operational capabilities. Further analysis and empirical investigation are needed to substantiate and authenticate the precision and reliability of the data.

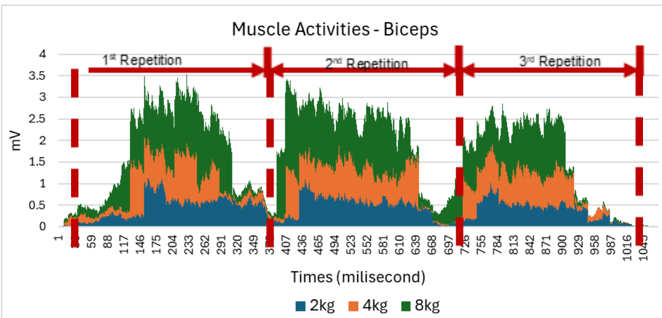

Figure 4. Muscle activities during measurement for lifting load.

4. Conclusions

This paper significantly contributes to the expanding literature on affordable and accessible biomedical monitoring solutions for monitoring muscle activities harvester. Integrating Arduino-based EMG systems with Bluetooth technology offers a cost-effective and user-friendly remote monitoring and analysis solution. The technology is promising in providing accurate and reliable data acquisition. Results from the prototype's functional test demonstrate its efficacy in capturing muscle activities in various scenarios.

This paper showed the viability of employing a cost-effective EMG system to monitor muscle activity in palm harvesters. It allows fellow authors to explore the correlation between muscle activity and worker productivity.

In short, this paper can serve as a guiding principle in developing machinery and harvesting tools, encouraging the integration of ergonomic design principles. Further work and validation could enhance the usability and effectiveness of Arduino-based EMG systems, particularly in real-world applications for muscle activities of operators in oil palm plantations.

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Conflict of interest

The authors declare no conflict of interest.

Author Contribution Statement

Mohd Rizal Ahmad, Nabilah Kamaliah Mustaffa, and Muhamad Izzat Fahmi Osman Tohpaeroh: Involved in developing the methodology and conducting data collection.

Mohd Rizal Ahmad, Ahmad Syazwan Ramli, and Mohd Azwan Mohd Bakri: Responsible for preparing the introduction and conducting the literature review.

Nabilah Kamaliah Mustaffa and Muhamad Izzat Fahmi Osman Tohpaeroh: Generated the visual data representations for the Results and Discussion sections.

References

[1] T. Raj, F. H. Hashim, A. B. Huddin, A. Hussain, M. F. Ibrahim, and P. M. Abdul, "Classification of oil palm fresh fruit maturity based on carotene content from Raman spectra," *Sci Rep*, vol. 11, no. 1, p. 18315, Sep. 2021, doi: https://doi.org/10.1038/s41598-021-97857-5.

[2] H.-H. Tao, E. M. Slade, K. J. Willis, J.-P. Caliman, and J. L. Snaddon, "Effects of soil management practices on soil fauna feeding activity in an Indonesian oil palm plantation," *Agric Ecosyst Environ*, vol. 218, pp. 133–140, Feb. 2016, doi: https://doi.org/10.1016/j.agee.2015.11.012.

[3] N. Myzabella, L. Fritschi, N. Merdith, S. El-Zaemey, H. Chih, and A. Reid, "Occupational Health and Safety in the Palm Oil Industry: A Systematic Review," *Int J Occup Environ Med*, vol. 10, no. 4, pp. 159–173, Oct. 2019, doi: https://doi.org/10.15171/ijoem.2019.1576.

[4] Y. G. Ng, S. B. M. Tamrin, W. M. Yik, I. S. M. Yussof, and I. Mori, "The Prevalence of Musculoskeletal Disorder and Association with Productivity Loss: A Preliminary Study among Labour Intensive Manual Harvesting Activities in Oil Palm Plantation," *Ind Health*, vol. 52, no. 1, pp. 78–85, 2014, doi: https://doi.org/10.2486/indhealth.2013-0017.

[5] M. Ahmed, M. Grillo, A. Taebi, M. Kaya, and P. Thibbotuwawa Gamage, "A Comprehensive Analysis of Trapezius Muscle EMG Activity in Relation to Stress and Meditation," *BioMedInformatics*, vol. 4, no. 2, pp. 1047–1058, Apr. 2024, doi: https://doi.org/10.3390/biomedinformatics4020058.

[6] D. H. Muhsen, A. B. Ghazali, T. Khatib, and I. A. Abed, "Extraction of Photovoltaic Module Model's Parameters Using an Improved Hybrid Differential evolution/electromagnetism-like Algorithm," Solar Energy, vol. 119, pp. 286–297, Sep. 2015, doi: https://doi.org/10.1016/j.solener.2015.07.008.

[7] A. Phinyomark, R. N. Khushaba, and E. Scheme, "Feature Extraction and Selection for Myoelectric Control Based on Wearable EMG Sensors," *Sensors*, vol. 18, no. 5, p. 1615, May 2018, doi: https://doi.org/10.3390/s18051615.

[8] R. Nemes et al., "Ipsilateral and Simultaneous Comparison of Responses from Acceleromyography- and Electromyography-based Neuromuscular Monitors," *Anesthesiology*, vol. 135, no. 4, pp. 597–611, Oct. 2021, doi: https://doi.org/10.1097/ALN.0000000000003896.

[9] T. Yu, K. Akhmadeev, E. Le Carpentier, Y. Aoustin, and D. Farina, "Highly Accurate Real-Time Decomposition of Single Channel Intramuscular EMG," *IEEE Trans Biomed Eng*, vol. 69, no. 2, pp. 746–757, Feb. 2022, doi: https://doi.org/10.1109/TBME.2021.3104621.

[10] N. Nazmi, M. Abdul Rahman, S.-I. Yamamoto, S. Ahmad, H. Zamzuri, and S. Mazlan, "A Review of Classification Techniques of EMG Signals during Isotonic and Isometric Contractions," *Sensors*, vol. 16, no. 8, p. 1304, Aug. 2016, doi: https://doi.org/10.3390/s16081304.

[11] R. Chowdhury, M. Reaz, M. Ali, A. Bakar, K. Chellappan, and T. Chang, "Surface Electromyography Signal Processing and

Classification Techniques," *Sensors*, vol. 13, no. 9, pp. 12431–12466, Sep. 2013, doi: https://doi.org/10.3390/s130912431.

[12] S. Fuentes del Toro, Y. Wei, E. Olmeda, L. Ren, W. Guowu, and V. Díaz, "Validation of a Low-Cost Electromyography (EMG) System via a Commercial and Accurate EMG Device: Pilot Study," *Sensors*, vol. 19, no. 23, p. 5214, Nov. 2019, doi https://doi.org/10.3390/s19235214.

[13] J. Nsaif Shehab, "DESIGN AND IMPLEMENTATION OF FACTORY SECURITY SYSTEM," *Journal of Engineering and Sustainable Development*, vol. 2018, no. 01, pp. 162–171, Jan. 2018, doi: https://doi.org/10.31272/jeasd.2018.1.13.

[14] R. T. H. Abbas Saleh Hassan, "SIMULATION OF RADIO FREQUENCY IDENTIFICATION BASED LIBRARY MANAGEMENT SYSTEM," *Journal of Engineering and Sustainable Development*, vol. 21, no. 4, pp. 161–170, Jul. 2017, [Online]. Available: https://jeasd.uomustansiriyah.edu.iq/index.php/jeasd/article/view/512

[15] G. Ehrmann, T. Blachowicz, S. V. Homburg, and A. Ehrmann, "Measuring Biosignals with Single Circuit Boards," *Bioengineering*, vol. 9, no. 2, p. 84, Feb. 2022, doi: https://doi.org/10.3390/bioengineering9020084.

[16] S. Zhao et al., "Wearable Physiological Monitoring System Based on Electrocardiography and Electromyography for Upper Limb Rehabilitation Training," *Sensors*, vol. 20, no. 17, p. 4861, Aug. 2020, doi: https://doi.org/10.3390/s20174861.

[17] H. Wu, M. Dyson, and K. Nazarpour, "Arduino-Based Myoelectric Control: Towards Longitudinal Study of Prosthesis Use," *Sensors*, vol. 21, no. 3, p. 763, Jan. 2021, doi: https://doi.org/10.3390/s21030763.

[18] S. Fuentes del Toro, Y. Wei, E. Olmeda, L. Ren, W. Guowu, and V. Díaz, "Validation of a Low-Cost Electromyography (EMG) System via a Commercial and Accurate EMG Device: Pilot Study," *Sensors*, vol. 19, no. 23, p. 5214, Nov. 2019, doi https://doi.org/10.3390/s19235214.

[19] O. J. Suarez, N. H. Díaz, and A. P. Garcia, "A real-time pattern recognition module via Matlab-Arduino interface," *in Proceedings of the LACCEI international Multi-conference for Engineering, Education and Technology, Latin American and Caribbean Consortium of Engineering Institutions, 2020*. doi: https://doi.org/10.18687/LACCEI2020.1.1.646.

[20] Y. S. A. Gumilang, K. Krisdianto, H. Haitsam, Moch. A. R. Fahreza, and A. Alfayid, "Design of Bluetooth Wireless Transporter Mecanum Wheeled Robot with Android Smartphone Controller for Moving Item," *ELKHA*, vol. 15, no. 1, p. 61, Apr. 2023, doi https://doi.org/10.26418/elkha.v15i1.63769.

[21] R. Maulana Hidayat, E. Hadi Purwanto, and A. E. Kristus Pramuko, "Prototype Of Wheel Suggestion Control Using Android Based On Arduino Uno R3," *Jurnal Inovatif : Inovasi Teknologi Informasi dan Informatika*, vol. 5, no. 2, p. 129, Oct. 2022, doi: https://doi.org/10.32832/inova-tif.v5i2.8509.

[22] G. M. U. Ghori and R. G. Luckwill, "Responses of the lower limb to load carrying in walking man," *Eur J Appl Physiol Occup Physiol*, vol. 54, no. 2, pp. 145–150, Aug. 1985, doi: https://doi.org/10.1007/BF02335921.

[23] O. Thamsuwan and P. W. Johnson, "Machine learning methods for electromyography error detection in field research: An application in full-shift field assessment of shoulder muscle activity in apple harvesting workers," *Appl Ergon*, vol. 98, p. 103607, Jan. 2022, doi: https://doi.org/10.1016/j.apergo.2021.103607.