PROGRESS IN ENGINEERING APPLICATION AND TECHNOLOGY
e-ISSN: 2773-5303

PEAT

Vol. 5 No. 1 (2024) 267-273
https://publisher.uthm.edu.my/periodicals/index.php/peat

Pallet Tilt Monitoring System with Immediate Notification

Nur Amyza Anuar[1], Nor Anija Jalaludin[1]*, Amirul Syafiq Sadun[1]

[1] *Faculty of Engineering Technology*
Universiti Tun Hussein Onn Malaysia, 84600, Pagoh, Johor, MALAYSIA

*Corresponding Author: noranija@uthm.edu.my
DOI: https://doi.org/10.30880/peat.2024.05.01.028

Article Info

Received: 28 December 2023
Accepted: 17 January 2024
Available online: 15 June 2024

Keywords

Pallet, Tilt, Monitoring System, Notification

Abstract

This project introduces a groundbreaking prototype of a Pallet Tilt Monitoring System with Immediate Notification. The system leverages the MPU6050 sensor to create a robust pallet management solution. The primary objectives encompass the design of a gyroscope-based monitoring system capable of detecting pallet tilt or inclination, integration with the Blynk platform for real-time monitoring, and implementation of an ESP8266-based notification system to alert responsible personnel when dangerous tilt angles are exceeded. Through this integration, the system significantly enhances workplace safety by promptly detecting pallet tilts, facilitating real-time monitoring, and ensuring timely notifications to prevent accidents or damages. Experimental results demonstrate the system's precision, with tilt angle readings exhibiting a low average percent error of around 2.5 percent. This comprehensive approach not only enhances operational efficiency but also fosters a safer and more proactive approach to pallet management, addressing crucial aspects of inventory control and workplace safety in the industry.

1. Introduction

Many industries demonstrate the crucial role of pallet management nowadays. In factories and industries, pallets serve as the main interface for a unit load [1]. Pallet management, in general, is the core of supply chain activities for various parties involved. However, in recent years, supply chain interruptions have become the norm for enterprises in important global marketplaces. This is primarily due to the poorly managed current usage of pallets in the industry, leading to losses and shortages of pallets as the main problems facing the pallet industry [2]. The background study emphasizes the pivotal role of pallet management in supply chain activities and the need for improved practices. The research focuses on developing a prototype system for comprehensive pallet tilt monitoring using the MPU6050 sensor, integrating gyroscope-based tilt detection, Blynk platform for real-time monitoring, and ESP8266 notifications for immediate alerts.

This project is focusing on the pallet instability during transit and delayed incident awareness which always happened in industrial pallet management [3]. Existing solutions are criticized for prolonged event reporting and insufficient pallet tilt detection capabilities. The research aims to address these challenges by presenting a prototype system that reduces accidents and safeguards products through prompt detection and notification of pallet tilts.

In this project, the monitoring system employs the MPU6050 sensor for tilt detection, integrates with the Blynk platform for real-time monitoring, and incorporates a notification system using ESP8266 to alert personnel when pallet tilt exceeds specified thresholds. The project scope encompasses the development of a monitoring system for detecting pallet tilt angles, notification of responsible personnel in case of exceedance, and integration with the Blynk platform for continuous monitoring of pallet tilt conditions.

Progress in Engineering Application and Technology Vol. 5 No. 1 (2024) p. 267-273

2. Background Research

In exploring previous research related to product condition monitoring systems, several notable projects have addressed diverse aspects. "Smart Pallets" presents wireless environmental sensing prototypes for pallet-level monitoring, emphasizing post-harvest conditions with millimeter-scale capabilities and ultra-low power consumption [4]. The "Real-Time Monitoring System for Shelf Life Estimation of Fruit and Vegetables" proposes a multiple non-linear regression model, integrating Wi-Fi connectivity for effective quality control during the post-harvest process [5]. An "Automatic Warehouse Inventory Monitoring System Based on Text Extraction Using Computer Vision" streamlines inventory verification through computer vision and optical character recognition [6]. The "Smart Air Quality Monitoring System" focuses on preventing health issues by measuring temperature and particle density, providing alerts during poor air quality [7]. The "Arduino-Based System for Monitoring and Protecting Overvoltage and Undervoltage" ensures the safety of electrical systems by measuring voltage and current with an Arduino Uno, transmitting data for graphical observation and protection against overvoltage and undervoltage scenarios [8].

Several previous research projects related to IoT-based smart monitoring systems are also highlighted. The first project, the "IoT-Based Smart Water Quality Monitoring System," focuses on measuring chemical, physical, and microbiological properties to provide warnings for potential threats in water bodies [9]. The second project introduces a "Baby Monitoring System by Using Arduino Uno," utilizing cry analysis technology and an integrated fan for automated cradle swings and temperature control [10]. The third project presents a "Smartphone Gimbal with MPU6050 Sensor," utilizing a microcontroller and MPU6050 sensor for a cost-effective and accurate smartphone stabilizing gimbal [11]. The fourth project, "Fall Detection Method Based on FD-DNN for Elderly People Using MPU6050," introduces a wearable module for fall detection using the MPU6050 sensor and a deep neural network [12]. The fifth project is a "Gas Leakage Detection and Alerting System by Using Arduino Uno and GSM Module," employing sensors to detect gas leaks and sending SMS alerts for warning [13]. Lastly, the "Women's Safety Device with GPS Tracking" project focuses on women's safety by transmitting location data, activating alarms, and incorporating a shock feature for self-defense [14].

This section provides essential information on key components crucial to the development of the Pallet Tilt Monitoring System. The ESP8266 Wi-Fi Module, developed by Espressif Systems, stands out for its affordability and adaptability in embedded IoT applications, integrating a 32-bit microprocessor with Wi-Fi capabilities for wireless connectivity [15]. The MPU6050 Accelerometer and Gyroscope Module offer a comprehensive solution with a single chip incorporating 3-Axis accelerometer and gyroscope functionalities, facilitating precise motion sensing for tilt detection [16]. Blynk, a platform created by Pavel Bayborodin, enables the development of mobile applications for remote monitoring and control of electronic devices, supporting various MCUs and prototyping boards [17]. The Arduino IDE, as an open-source electronics prototyping platform, provides a user-friendly environment for code development and microcontroller programming [18]. Lastly, Proteus Software, designed by Labcenter Electronics, serves as a versatile tool for electronic circuit design, simulation, and PCB layout creation [19]. Together, these components contribute to the efficient and integrated functionality of the Pallet Tilt Monitoring System.

3. Methodology

The methodology section provides a detailed account of the project's methods, approaches, and designs, with a focus on justifying choices based on practical applicability. The Pallet Tilt Monitoring System prototype integrates a gyroscope-based tilt detection system, Blynk platform monitoring, and ESP8266 notifications. The use of sensors enhances pallet connectivity, forming the basis of the 'smart pallet' concept, with the overall aim of optimizing supply chain efficiency for time and cost savings.

Fig. 1 shows the block diagram illustrates the systematic flow of information within the Pallet Tilt Monitoring System, featuring a power bank or any small electrical device as the power source. The system employs an MPU6050 sensor to measure pallet tilt, with the ESP8266 serving as the microcontroller. The ESP8266 processes data from the MPU6050 and transmits it to the Blynk server over Wi-Fi. The Blynk application displays the received data and issues notifications if the tilt angle surpasses a predetermined threshold, leveraging Internet of Things (IoT) functionality for real-time monitoring and alerts.

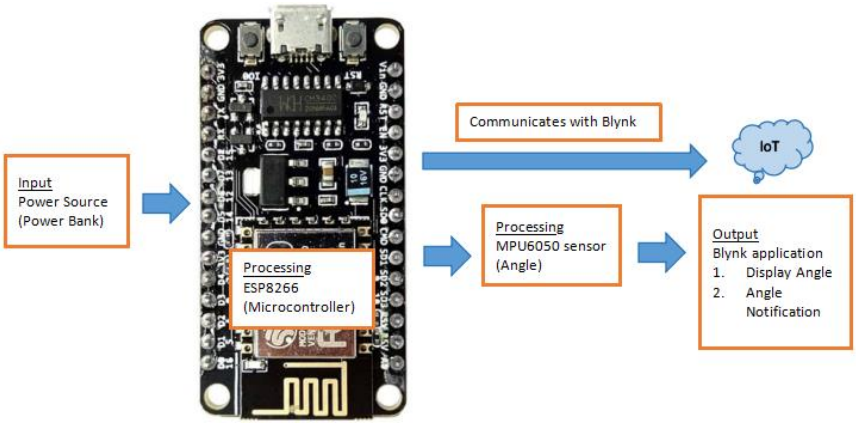

Fig. 1 *Detailed System Block Diagram of Pallet Tilt Monitoring System*

Fig. 2 shows the 3D design of this Pallet Tilt Monitoring System. The design was created using AutoCAD, showcasing the 3D perspectives. These designs illustrate the prototype developed towards the project's conclusion, featuring a visual representation of a pallet with an attached box beneath it to accommodate all the utilized components and sensors used.

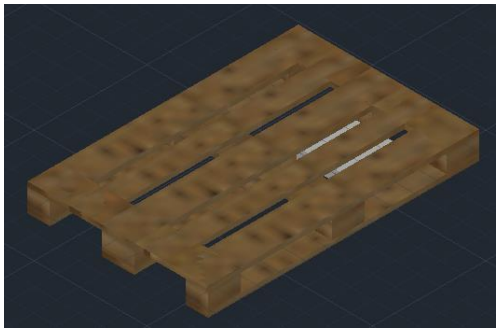

Fig. 2 *3D Design of Pallet Tilt Monitoring System*

In the circuit wiring diagram depicted in Fig. 3, the ESP8266 functions as the primary control unit for the Pallet Tilt Monitoring System prototype. The MPU6050 sensor, responsible for measuring pallet tilt and inclination, is connected to the ESP8266 via the I2C protocol, with the SCL and SDA lines linked to analog pins D1 and D2 of the ESP8266, respectively. Additionally, the ESP8266 module enables Wi-Fi communication, facilitating the transmission of data to the Blynk server for real-time monitoring and notifications, as illustrated.

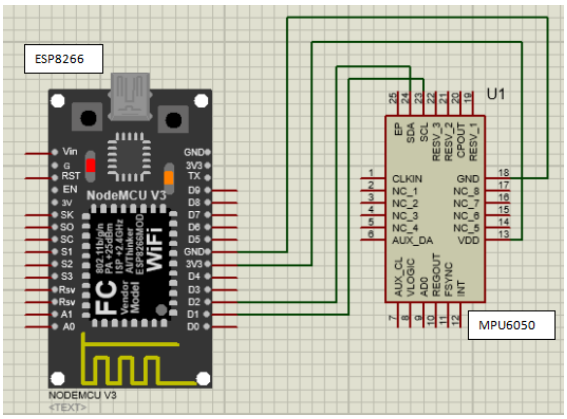

Fig. 3 *Schematic Diagram of Pallet Tilt Monitoring System*

4. Result and Analysis

This section summarizes the findings of the study, which involved conducting analyses and research to evaluate the efficiency and effectiveness of the prototype of Pallet Tilt Monitoring System with Immediate Notification. The system utilizes the MPU6050 gyroscope sensor to monitor the tilt angle of the pallet throughout the

Progress in Engineering Application and Technology Vol. 5 No. 1 (2024) p. 267-273

shipping supply chain, aiming to prevent damage to the goods carried and the pallet itself. The ESP8266 then will establish a Wi-Fi connection to enable the display of real-time monitoring data of the pallet tilt condition on the Blynk application. Simultaneously, the ESP8266 also acts as the microcontroller, notifying responsible personnel when the tilt angle exceeds the dangerous level by sending a notification message to the Blynk application on the user's mobile phone.

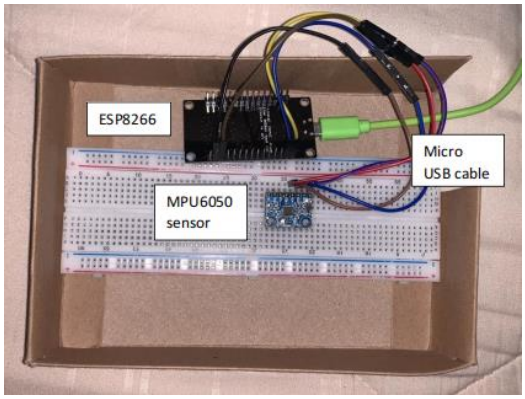

Fig. 4 *Tilt Angle Monitoring System Configuration*

Physical connection between ESP8266 and MPU6050 gyroscope sensor is shown in Fig. 4. These components are used to monitor the tilt angle of the pallets as in the first objective. Several experiments were conducted by using MPU6050 gyroscope sensor to collect data for angles X and Y. To obtain the data, it was necessary to identify the different angles of the components in the X and Y directions initially. Next, the expected angles in the X and Y directions were recorded. Finally, the MPU6050 gyroscope sensor was used to measure the real-time angles in each trial for X and Y.

Table 1 presents trial results for the Pallet Tilt Monitoring System prototype, comparing expected and measured tilt angles X. In trials 1 and 4, the measured angles precisely match the expected angles (0° and 110°, respectively). However, in trials 2 and 3, slight differences of 1° are observed, resulting in a 2.5% error. Overall, the system demonstrates accurate tilt measurements, with a minimal percentage error.

Table 1 *Tilt Angle X Result*

Trial	Expected Angle (°)	Measured Angle (°)	Difference (°)	Error (%)
1	0	0	0	0
2	70	71	1	2.5
3	90	89	1	2.5
4	110	110	0	0

Table 2 displays trial results for the Pallet Tilt Monitoring System prototype, comparing expected and measured tilt angles Y. In trials 1 and 3, the measured angles precisely match the expected angles (0° and 90°, respectively). In trials 2 and 4, a slight difference of 1° is observed, resulting in a 2.5% error. Overall, the system demonstrates accurate tilt measurements with minimal percentage error in the trials.

Table 2 *Tilt Angle Y Result*

Trial	Expected Angle (°)	Measured Angle (°)	Difference (°)	Error (%)
1	0	0	0	0
2	70	69	1	2.5
3	90	90	0	0
4	110	111	1	2.5

The obtained results of the Blynk application performance are presented in Table 3. The evaluation feedback for the Pallet Tilt Monitoring System application is positive. Navigation between gauges is user-friendly, and real-time visualization of pallet tilt data is clear. Widget interactivity is prompt, responding to user inputs efficiently. Data synchronization to Blynk occurs almost instantly at a speed of 1 second. Notifications are timely within the

application but may experience a slight delay of 8-10 seconds when received via Gmail. The application remains responsive and accurate across different devices, even after extended use.

Table 3 *Blynk Application Performance Result*

Criteria	**Result/Feedback**
Navigation	Navigating between the widgets used which are the gauges in the application is straightforward.
Real-time Visualization	Pallet's tilt data of angle X and Y are shown clearly and in real time using the gauges widgets.
Widget Interactivity	The gauges widgets respond on time to user inputs retrieved from MPU6050 and provide real-time data.
Data Sync speed	The pallet's tilt data from the hardware to Blynk was displayed almost instantly with a data sync speed of 1 sec.
Notification Timing	Notifications are sent 1-2 secs in the application after the threshold is exceeded but can up to 8-10 secs in Gmail.
App Responsiveness	The application runs smoothly on a variety of devices and remains accurate even after long periods of use.

The example of a notification message sent by using the ESP8266 to the Blynk application is shown in Fig. 6. When the components' angle exceeds the dangerous thresholds, which is less than 60° or more than 120° [20], it will give a notification alert on the Blynk application on the user's mobile phone.

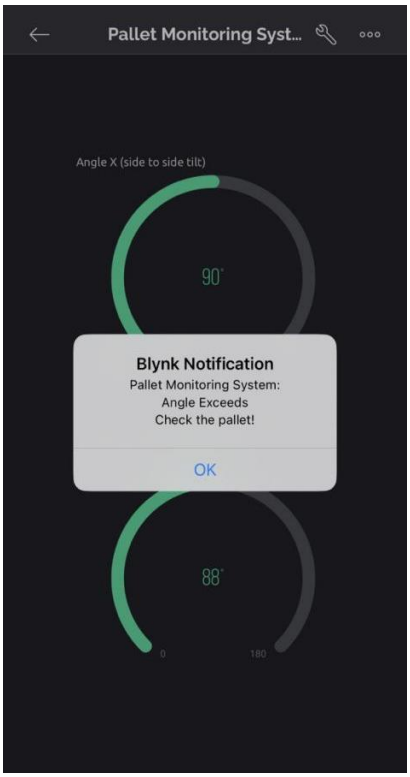

Fig. 6 *Example of a Notification Message on Blynk*

Table 4 summarizes trials for the Pallet Tilt Monitoring System, indicating precise matching of expected and measured angles for both X-axis and Y-axis tilt. Thresholds are consistently exceeded at specific times in each trial, with Blynk notifications promptly received simultaneously, reflecting an immediate response to threshold breaches.

Table 4 *Notification System Effectiveness Result*

Trial	Expected Angle	Measured Angle	Threshold Exceeded Time	Blynk Notification Received Time
1 (X-axis)	60	60	5:59:22 pm	5:59:22 pm
2 (X-axis)	120	120	6:11:35 pm	6:11:35 pm
3 (Y-axis)	60	60	7:03:58 pm	7:03:58 pm
4 (Y-axis)	120	120	7:15:13 pm	7:15:13 pm

5. Conclusion

In conclusion, the project has successfully achieved its key objectives, resulting in the development of an integrated Pallet Tilt Monitoring System. Implementation of the MPU6050 gyroscope sensor has enabled precise detection of pallet tilt angles, providing real-time data for improved monitoring capabilities. The integration with the Blynk application fulfills the goal of displaying data, enhancing operational efficiency, and enabling proactive responses to pallet tilt conditions. Additionally, the ESP8266 module is effectively employed to establish a notification system, promptly alerting relevant individuals when pallet tilt angles exceed predetermined limits. The successful combination of gyroscope sensing, Blynk data monitoring, and notifications culminates in the creation of a functional prototype for the Pallet Tilt Monitoring System with Immediate Notification. The Pallet Tilt Monitoring System with Immediate Notification project's achieved goals point to potential areas for improvement going forward. For wider deployment, scalability, affordability, and integration with technologies like blockchain or RFID are advised. Incorporating wireless power choices, such solar panels or rechargeable batteries, can increase mobility. Furthermore, the use of data analytics techniques, such as machine learning algorithms, can facilitate predictive maintenance and early problem detection, improving pallet management and decreasing downtime.

Acknowledgement

The authors express heartfelt gratitude to the faculty members of Fakulti Teknologi Kejuruteraan for their knowledge-sharing and resources. The authors extend their appreciation to everyone who contributed, as their support was instrumental in achieving this milestone.

References

[1] Orlandi, E. C. (2017). The values of pallets: An ethnography of exchange in the warehouse of an Italian supermarket. Journal of Material Culture, 22(1), 19–33. https://doi.org/10.1177/1359183516662674

[2] Attinasi, M. G., Balatti, M., Mancini, M., & Metelli, L. (2021, August). Supply chain disruptions and the effects on the global economy. ECB Economic Bulletin, Issue 8/2021.

[3] Alonso, M. T., Martinez-Sykora, A., Alvarez-Valdes, R., & Parreño, F. (2022). The pallet-loading vehicle routing problem with stability constraints: The pallet-loading vehicle routing problem with stability constraints. Second revision. European Journal of Operational Research, 302(3), 860–873. https://doi.org/10.1016/j.ejor.2022.01.035

[4] Saffari, A., Iyer, V., Kapetanovic, Z., & Ranganathan, V. (2022). Smart Pallets: Toward Self-Powered Pallet-level Environmental Sensors for Food Supply Chains. SenSys 2022 - Proceedings of the 20th ACM Conference on Embedded Networked Sensor Systems, 1130–1135. https://doi.org/10.1145/3560905.3568420

[5] Torres-Sánchez, R., Martínez-Zafra, M. T., Castillejo, N., Guillamón-Frutos, A., & Artés-Hernández, F. (2020). Real-time monitoring system for shelf life estimation of fruit and vegetables. Sensors (Switzerland), 20(7). https://doi.org/10.3390/s20071860

[6] LeBlanc, R. (2023, February 2). Pallet Earth launches trackable, nestable composite pallet for UK and European market. Reusable Packaging News. https://packagingrevolution.net/pallet-earth-nestable-pallet/

[7] Fadzly, M. K., Yiling, Rosli, M. F., Amarul, T., & Effendi, M. S. M. (2020). Smart Air Quality Monitoring System Using Arduino Mega. IOP Conference Series: Materials Science and Engineering, 864(1). https://doi.org/10.1088/1757-899X/864/1/012215

[8] Duc Tung, D., & Minh Khoa, N. (2019). An Arduino-Based System for Monitoring and Protecting Overvoltage and Undervoltage. In Technology & Applied Science Research (Vol. 9, Issue 3). www.etasr.com
[9] Lakshmikantha, V., Hiriyannagowda, A., Manjunath, A., Patted, A., Basavaiah, J., & Anthony, A. A. (2021). IoT based smart water quality monitoring system. Global Transitions Proceedings, 2(2), 181–186. https://doi.org/10.1016/j.gltp.2021.08.062
[10] Azrul, W., Nazri, W. A., & Harun, F. (2022). Baby Monitoring System by using Arduino Uno. In Journal of Engineering Technology (Vol. 10, Issue 1).
[11] Rafiq, A. A., Rohman, W. N., & Riyanto, S. D. (2020). Development of a simple and low-cost smartphone gimbal with MPU-6050 sensor. Journal of Robotics and Control (JRC), 1(4), 136–140. https://doi.org/10.18196/jrc.1428
[12] Liu, L., Hou, Y., He, J., Lungu, J., & Dong, R. (2020). An energy-efficient fall detection method based on FD-DNN for elderly people. Sensors (Switzerland), 20(15), 1–16. https://doi.org/10.3390/s20154192
[13] Bushra Shahewaz, S., & Rajendra Prasad, C. (2020). Gas leakage detection and alerting system using Arduino Uno. Global Journal of Engineering and Technology Advances, 2020(03), 29–035. https://doi.org/10.30574/gjeta
[14] Wankhade, H., Mahajan, S., & Gopnarayan, Prof. S. P. (2022). Women's Safety Device with GPS Tracking and Alert. International Journal for Research in Applied Science and Engineering Technology, 10(8), 1177–1183. https://doi.org/10.22214/ijraset.2022.4638
[15] Hübschmann, I. (2020, August 10). ESP8266 for IoT: A Complete Guide. Nabto. https://www.nabto.com/esp8266-for-iot-complete-guide/
[16] MPU6050 Accelerometer and Gyroscope Module. (2021, March 17). Components101. https://components101.com/sensors/mpu6050-module
[17] Media's, E., . S., & Rif'an, M. (2019). Internet of Things (IoT): BLYNK Framework for Smart Home. KnE Social Sciences, 3(12), 579. https://doi.org/10.18502/kss.v3i12.4128
[18] Armenta, A. (2022, September 8). Introduction to Arduino: History, Hardware, and Software. Control Automation. https://control.com/technical-articles/introduction-to-arduino-history-hardware-and-software/
[19] Albertini, N., Baldini, J., Dal Pino, A., Lazzari, F., Legnaioli, S., & Barone, V. (2022). PROTEUS: an immersive tool for exploring the world of cultural heritage across space and time scales. Heritage Science, 10(1). https://doi.org/10.1186/s40494-022-00708-3
[20] Singh, J., Sewell, T., Newton, L., & Saha, K. (n.d.). Evaluation of Stability of Unit Loads for Tilt and Shock Events During Distribution 73 Evaluation of Stability of Unit Loads for Tilt and Shock Events During Distribution.