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Enhancing Safety in Cargo Handling Units Using Thermal and Motion IoT Sensors

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Abstract

To improve supply chain efficiency by establishing real-time communication via Internet of Things (IoT) devices between cargo units and Logistics Control Systems (LCS). The method makes it possible to continuously monitor characteristics like location, temperature, humidity, and handling affects by carefully placing IoT sensors within cargo containers. These Internet of Things (IoT) devices work together to create a network that sends data in real time to a centralized LCS platform. This data gives logistics operators fast insights for proactive disruption response, risk mitigation, and optimized route planning. The research uses encryption techniques, redundancy plans, and flexible software interfaces to address issues with data security, device dependability, and integration into current infrastructure. Furthermore, by integrating machine learning and predictive analytics, the LCS can anticipate potential problems, which helps promotes increased customer happiness, decreased losses, and greater operational performance in contemporary logistics and freight transportation.

Introduction

Effective cargo handling and transportation are critical components of corporate success and customer happiness in today's global trade and logistics environment. However, the difficulties associated with this complex process—such as abrupt shocks during aircraft transportation, fluctuating humidity and temperature, and the critical requirement for real time visibility into cargo locations—call for creative solutions to maximize logistics operations. Adopting Internet of Things (IoT) technologies has caused a paradigm shift that makes it imperative to handle these issues thoroughly. Unexpected shocks throughout the complex stages of aircraft transportation are a major worry because they present a tan- Find the relevant funding source here. Remove this if there are none. Eligible risk to the integrity of the cargo being transported. The suggested IoT solution suggests equipping cargo units with accelerometers and gyroscopes as a response to this. These sensors can detect shocks in real time and send data to a centralized system quickly, giving logistics operators.

early warning signs of possible cargo damage. In addition to assisting with the preservation of delicate goods, this real time monitoring and alert system enables prompt responses to lessen the effects of unforeseen shocks. Unexpected shocks throughout the complex stages of aircraft transportation are a major worry because they present a risk to the integrity of the cargo being transported. This solution involves equipping cargo units with accelerometers and gyroscopes as a response to this. These sensors can detect shocks in real time and send data to a centralized system quickly, giving logistics operators early warning signs of possible cargo damage. In addition to assisting with the preservation of delicate goods, this real-time monitoring and alert system enables prompt responses to lessen the effects of unforeseen shocks. The focus is on enhancing the robustness and versatility of robots, especially in more complex real-world environments, as testing initially conducted on simple line tracks revealed the need for improved robustness. The lack of real-time visibility into cargo locations represents a logistical blind spot that can lead to inefficiencies, operational delays, and heightened risks of theft or loss. To address this challenge, the proposed solution advocates for the implementation of IoT-based GPS tracking systems within cargo units. These modules provide live location data that is seamlessly transmitted to the LCS, empowering logistics operators with real-time insights into cargo movements. This live GPS tracking not only facilitates optimized route planning but also enables prompt responses to deviations or unforeseen events, enhancing overall operational efficiency. The amalgamation of IoT technologies into cargo handling operations offers a transformative approach to mitigate challenges inherent in logistics. By strategically addressing sudden shocks, environmental variables, and the necessity for real time visibility, this proposed solution aims to redefine cargo handling paradigms, fostering enhanced efficiency, security, and reliability within the intricate web of global logistics networks.

Motivation

The identification of significant flaws in the current logistics paradigm and the realization of the revolutionary potential of Internet of Things (IoT) technologies serve as the driving forces behind the investigation of IoT integration into cargo handling operations. Improving operational efficiency is the driving force behind this motivation . The demands of today's dynamic global supply chains frequently prove too much for traditional cargo handling techniques to handle, which leads to subpar responsiveness and adaptability. The logistics sector can achieve previously unheard-of agility by implementing IoT technology, notably in the areas of real-time shock detection, continuous environmental monitoring, and live GPS tracking. In order to satisfy the changing demands of contemporary supply chains, this adaptability translates into improved operational efficiency overall, streamlined workflows, and quick decision-making. Maintaining the integrity of the products being carried is another strong incentive. Cargo quality can be compromised by abrupt shocks during flight and insufficient control over humidity and temperature, particularly with regard to perishable or delicate goods. Logistics operators may proactively handle shocks and environmental fluctuations by adding IoT sensors that provide real-time monitoring and data transfer. This increases the supply chain's dependability and resilience by protecting cargo quality and reducing losses from spoiling or damage. The goal of maximizing resource use is a significant source of motivation. Lack of real-time visibility into freight movements can lead to inefficient resource allocation and route planning in traditional logistics procedures. This problem is solved by IoT-enabled GPS tracking, which gives accurate location data instantly. By using this data, logistics operators may minimize operating costs and promote a more sustainable logistics ecosystem by streamlining routes, cutting down on delays, and more effectively allocating resources. An additional motivating aspect is the need to reduce hazards related to cargo handling and security issues. There are security hazards associated with inadequate sight into cargo locations, such as the possibility of theft or loss during transit. A strong security mechanism is established by the integration of real-time GPS tracking and shock detection features. Logistics operators are in line with the industry trend of embracing technological improvements for better security measures, as they can react quickly to deviations or unforeseen events, minimizing risks and enhancing the protection of high value goods. Moreover, the motivation stems from the broader trend of adapting to industry shifts and meeting evolving consumer expectations. The logistics industry is undergoing rapid technological advancements, and businesses must adapt to stay competitive. Embracing IoT aligns with this digital transformation trend, positioning companies at the forefront of innovation.

Additionally, consumers increasingly expect real-time tracking and transparency in the delivery of goods IoT technologies contribute to meeting these expectations by providing a seamless and transparent supply chain, fostering customer satisfaction, trust, and loyalty.

Objectives

***Implement Real-time Shock Detection*:** Integrate IoT accelerometers and gyroscopes within cargo units to detect and transmit real-time data on sudden shocks during aircraft transportation.

***Enable Continuous Environmental Monitoring*:** Incorporate IoT temperature and humidity sensors into cargo units to provide continuous monitoring of environmental conditions, ensuring that cargo, especially temperature sensitive goods, remains within specified parameters.

Facilitate Live GPS Tracking: Implement IoT-based GPS tracking systems in cargo units to enable live tracking of cargo movements. Transmit real-time location data to the Logistics Control System (LCS) for optimized route planning and enhanced visibility.

Develop a Centralized Logistics Control System (LCS): Create a centralized LCS that integrates data from various IoT sensors, providing a unified platform for monitoring shocks, environmental conditions, and live GPS data.

***Implement Automated Alerts and Notifications*:** Develop a system of automated alerts and notifications triggered by deviations from specified environmental conditions or sudden shocks. Enable logistics operators to respond promptly to potential issues.

Enhance Operational Efficiency: Streamline cargo handling workflows by leveraging real-time data insights. Enable logistics operators to make informed decisions, optimize routes, and allocate resources efficiently.

Optimize Route Planning: Utilize live GPS tracking data to optimize route planning, reducing transit times, minimizing delays, and improving overall transportation efficiency.

Problem Statement

With the use of Internet of Things (IoT) technology, this project seeks to transform logistics' approach to cargo handling by tackling major obstacles in the transportation chain. Several obstacles stand in the way of effective logistics, including temperature and humidity variations, abrupt shocks during airplane transportation, and a lack of real-time sight into cargo locations. It is suggested that cargo units be equipped with accelerometers and gyroscopes enabled by the Internet of Things to lessen the effects of unexpected shocks. A centralized system will receive real-time stress data from these sensors, enabling prompt responses to any possible cargo damage. Furthermore, cargo units equipped with Internet of Things-based temperature and humidity sensors will continuously monitor the surrounding environment and feed real-time data to the Logistics Control System. (LCS). As a component of the Internet of Things, the live GPS monitoring system guarantees real-time visibility into freight movements, allowing for proactive responses to deviations and optimized routes. Data-driven decision-making is made easier by the centralized LCS, which serves as a hub for monitoring and integrating data from several IoT sensors. To protect sensitive cargo and operational data, security measures, such as encrypted communication channels and secure access controls, will be put in place. This will guarantee a complete and secure Internet of Things solution for increased cargo handling logistics efficiency.

Existing system

The existing system includes obstacle avoidance logic, line identification, PID control, and sensor fusion techniques. The focus of the study is on controlled testing with different line configurations and course planning based on sensor data. The main goal is to use AI and machine learning to increase the autonomy and intelligence of robots. The review proposes a paradigm change that would allow robots to learn and map environments for greater flexibility, in contrast to existing systems that follow predetermined lines. The development of an IoT-enabled shipping container with location and environmental tracking capabilities. An Arduino microcontroller is utilized in the system to integrate several sensors, such as infrared, pressure, heat, position, and vibration sensors. Wheels and motor drivers make movement easier. The assessment indicates that integration with contemporary IoT infrastructure might greatly improve fleet management, monitoring, and coordination, even though the networking capabilities are now restricted. The possibility for enhanced cloud platform connectivity is highlighted as a means of optimizing the overall functionality and efficiency of shipping container systems. The use of the Internet of Things (IoT) in smart logistics is examined with a focus on software-related topics including using the Arduino IDE's Embedded C programming language to program an Arduino microcontroller and implementing proportional-integral-derivative (PID) control to modify the robot's speed and trajectory. Infrared, pressure, heat, location, and vibration sensors are among the sophisticated sensors and integration mechanisms that the report mentions as being necessary for line-following robots. It draws attention to the possibilities for improved precision and flexibility made possible by advanced techniques for sensor fusion and integration. The application of augmented weight sensing for aviation cargo management includes DC motors for propulsion and steering, motor drivers for motor control, wheels and chassis for physical movement along the line, and Arduino Uno for processing sensor inputs and controlling robot movement. The emphasis is on improving robot robustness and versatility, particularly in more complicated real-world contexts, since the necessity for enhanced robustness was first identified through testing on straightforward line tracks. The body of research emphasizes how critical it is to develop cargo handling robots' capabilities in order to meet the demands of a variety of complex operational environments. The proposed system incorporates PID control and sensor fusion algorithms, along with line detection and obstacle avoidance logic. The study emphasizes path planning based on sensor data and controlled testing with various line configurations. The key objective is to enhance the intelligence and autonomy of robots through machine learning and AI. Unlike traditional approaches that follow preset lines, the review advocates for a paradigm shift, enabling robots to learn and map environments for increased flexibility. The integration of reinforcement learning methods is suggested to optimize path planning and navigation, emphasizing the potential for improved efficiency and adaptability in cargo carrier systems.

Proposed methodology System specific requirements

Software Requirements

- *Programming Languages:* Arduino with C/C++ Backend
- *Development Languages:* Python, Java, Node.js;
- *Web Development Languages:* HTML, CSS, JavaScript *Security Libraries and Protocols*: SSL/TLS for Secure Communication Security Libraries (e.g., OpenSSL)
- *Testing Frameworks* :Unit IoT Device Simulation Tools

***Hardware Requirements*:**

- ***MPU6050 sensor, Gyroscope and Accelerometer:***Combining an accelerometer and gyroscope, the MPU6050 sensor is a flexible motion-tracking tool that allows accurate rotation and acceleration measurement in a range of electronic applications. It is perfect for projects needing motion detection and orientation tracking because of its small size and precise sensing capabilities.
- ***DHT22, Temperature and humidity sensor:*** Accurate measurements of the ambient temperature and humidity are provided by the DHT22 temperature and humidity sensor. It is a popular option for monitoring and managing indoor climate conditions in a variety of applications, such as weather stations, greenhouses, and HVAC systems, because to its dependability, affordability, and digital output.
- ***Zigbee module for Wireless communication:***Short-range wireless communication between devices is made easier by the Zigbee module. Zigbee, which enables smooth connectivity and data transmission across networked devices, is used in sensor networks, industrial control systems, and home automation because of its powerful networking capabilities and low power consumption.
- ***NEO-6M GPS Module:***One well-liked option for getting accurate positioning data in real-time is the NEO-6M GPS module. It is appropriate for navigation, mapping, and location-based applications in drones, IoT devices, and other projects where precise geographic information is crucial because to its high sensitivity and quick capture of satellite signals.
- ***Buzzer:*** A tiny sound-producing gadget that is simple to link with the Arduino Uno is a buzzer. The buzzer's frequency, length, and patterns can be precisely controlled thanks to the Arduino Uno's programmability, which makes it ideal for a variety of tasks, including interactive projects and musical applications in addition to basic sound signalling.
- ***Arduino Uno:***The Arduino Uno is a popular microcontroller board widely used in electronics projects due to its simplicity and versatility. It features numerous digital and analog input/output pins, making it ideal for controlling various components and sensors.

List of Analysis Tasks

- ***Sensor Initialization:*** Initialize the gyroscope sensor (MPU6050) for monitoring the movement and orientation of the packages. Initialize the DHT22 temperature and humidity sensor to track environmental conditions
- ***Defining Safety Specifications:*** Define safety specifications, including the maximum allowed tilt angle, vibration level, shock level, temperature range, and humidity range.
- ***Continuous Sensor Monitoring:*** Continuously monitor sensor data from the gyroscope sensor, focusing on the X, Y, and Z axes, to understand package movement and stability. Continuously monitor data from the DHT22 sensor to track temperature and humidity conditions.
- ***Calculating Safety Status:*** A Utilize the collected sensor data to calculate the safety status of the packages, considering factors like tilt, vibration, shock, temperature, and humidity
- ***Generating Safety Status Message:*** Generate user-friendly safety status messages, such as "Safe" or "Not Safe," based on the assessment of sensor data. These messages are designed for easy comprehension by logistics professionals.

Use case diagram for the Cargo Handling Unit

1. BLOCK DIAGRAM for the Cargo Handling Unit

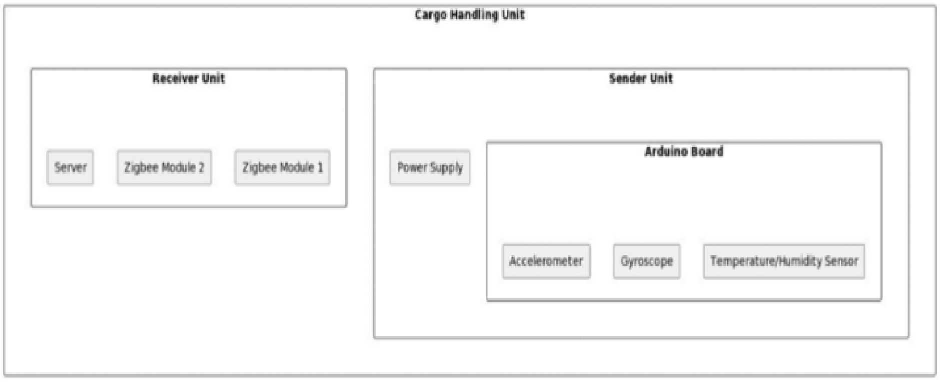

Fig. 1. BLOCK DIAGRAM for the Cargo Handling Unit

2. STATE CHART DIAGRAM for the Cargo Handling Unit

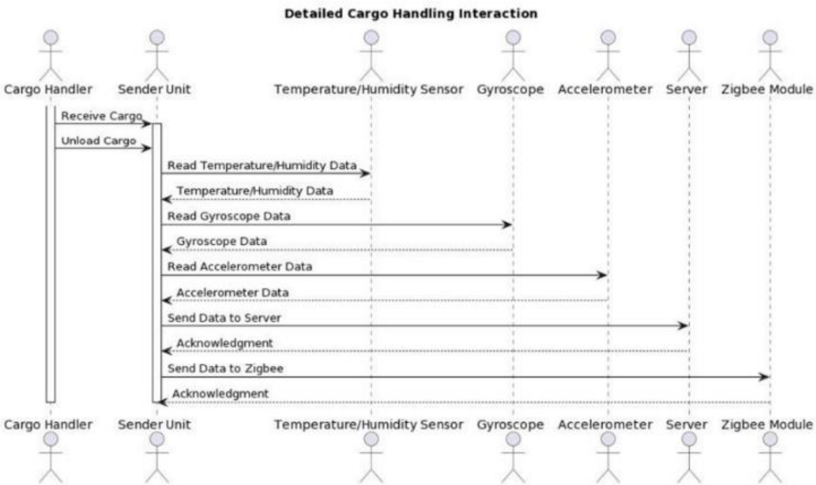

Fig. 2. STATE CHART DIAGRAM for the Cargo Handling Unit

Simulation of work done

Accelerometer & Gyroscope MPU6050

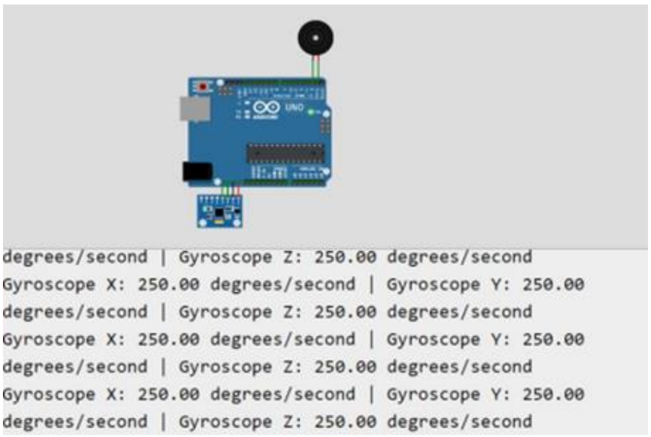

Fig. 3. Accelerometer & Gyroscope MPU6050

Connections for MPU6050 Sensor:

- VCC of MPU6050 to 5V pin of Arduino Uno.
- GND of MPU6050 to GND pin of Arduino Uno.
- SCL (Serial Clock Line) of MPU6050 to A5 pin of Arduino Uno.
- SDA (Serial Data Line) of MPU6050 to A4 pin of Arduino Uno.

Connections for Buzzer:

- Connect the positive (+) leg of the buzzer to digital pin 8 of Arduino Uno.
- Connect the negative (-) leg of the buzzer to any GND pin of Arduino Uno.

Temperature & humidity sensor DHT22

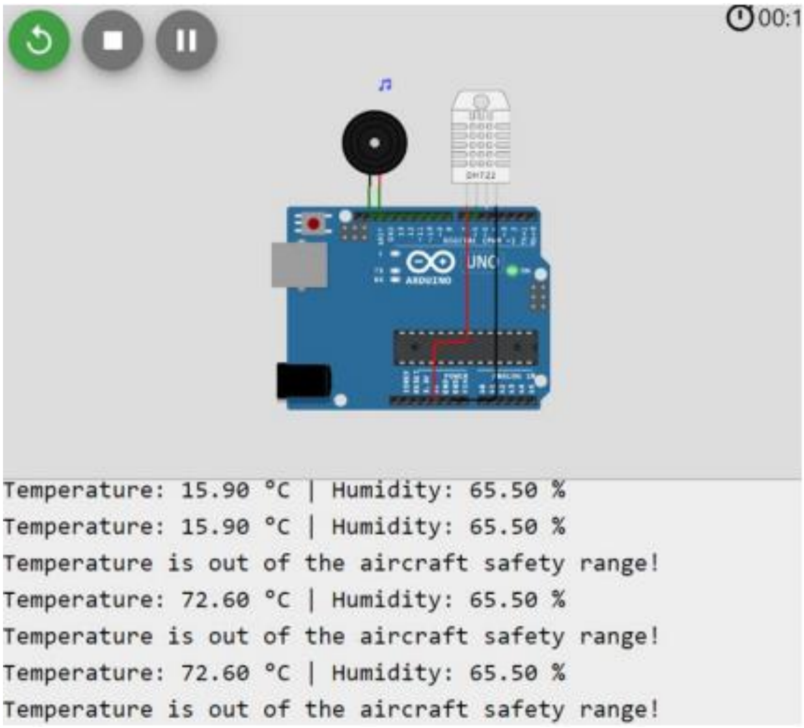

Fig. 4. Temperature & humidity sensor DHT22

Connections for DHT22 Sensor:

- VCC of DHT22 to 5V pin of Arduino Uno.
- GND of DHT22 to GND pin of Arduino Uno.
- OUT of DHT22 to Digital Pin 2 of Arduino Uno.

Connections for Buzzer:

- Connect the positive (+) leg of the buzzer to Digital Pin 8 of Arduino Uno.
- Connect the negative (-) leg of the buzzer to any GND pin of Arduino Uno

Sensor Calibration and Data Processing

The following thresholds for safety assessment:

- **Altitude Change Threshold**: 10.5 m/s²
- **Direction Change Threshold**: 10.5 degrees/s
- **Temperature Change Threshold**: 25°C
- **Humidity Change Threshold**: 70% Continuously reads and processes sensor data to evaluate the

safety status of the cargo. Altitude and orientation changes are determined using the Y-axis acceleration and gyroscope data from the MPU6050 sensor. Temperature and humidity data are obtained from the DHT22

Safety Assessment and Alert Mechanism:
Checks the monitored parameters against the predefined safety thresholds. If any of the parameters exceed the thresholds, the buzzer is activated with a specific frequency corresponding to the detected parameter to alert about potential safety concerns.
Integration with Logistics Control System (LCS):
To provide centralized monitoring and real-time alerts to logistics professionals, the system is integrated with an LCS. The Arduino code includes an HTTP client to transmit the safety status information to the LCS platform using an HTTP POST request. The LCS platform offers a designated endpoint (**/upload-safety-status**) to receive and process the safety status data transmitted from the device.

Conclusion

The development of a comprehensive safety monitoring system for package handling represents a critical step in ensuring the integrity and security of transported goods. This project focused on leveraging sensor technology to assess and maintain the safety status of packages during transit. By integrating sensors like the MPU6050 and DHT22, this system enables real-time monitoring of various environmental factors affecting package safety. The MPU6050 provides crucial data on package orientation and movement, allowing the system to detect excessive tilts along different axes. Simultaneously, the DHT22 sensor tracks temperature and humidity variations that might impact the cargo's integrity. The system's core functionality revolves around continuous data collection and analysis. By setting predefined safety thresholds for tilt angles, temperature, and humidity, the system distinguishes between safe and potentially compromised packages. Whenever the sensor readings exceed these thresholds, indicating potential safety risks, the system triggers alerts to mitigate these concerns. The inclusion of a buzzer serves as an immediate alert mechanism, providing auditory feedback when the package experiences unsafe conditions. This rapid notification system is vital for prompt action, allowing logistics personnel to intervene and take corrective measures before any damage occurs. Future iterations of this system could involve enhancing its capabilities. Integrating GPS connectivity could offer precise location data, further enriching the safety assessment process. Additionally, integrating HTTP client capabilities for data transmission to logistics control systems would streamline real-time monitoring and enable swift responses to safety concerns. In conclusion, this project's sensor-based safety monitoring system stands as a proactive solution for ensuring cargo safety during transportation. Its ability to detect and alert against environmental stressors safeguards packages, reducing potential losses and enhancing the reliability of the logistics chain. As technology advances, continuous refinement and expansion will be crucial to meeting the evolving demands of the logistics industry.

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