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High-Precision GPS Tracker for Monitoring Agricultural Sprayer Drone Operations

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Abstract

Efficient and precise pesticide application is critical in modern agriculture, especially when using drone technology. To ensure that spraying operations are carried out accurately in the intended locations, a reliable tracking system is essential. This newly developed Agriculture Sprayer Drone Tracker addresses this need through several key improvements over traditional methods. Previously, monitoring was performed using wired connections to check the tank, but the new system employs a wireless LoRa solution housed in a robust IP67-rated enclosure for better durability and flexibility.The tracker features a custom-designed GPS board based on the u-blox F9P module, providing high-precision location data. The GPS antenna has been optimized for a more compact form factor, resulting in a smaller, more portable device. Data is logged directly to an SD card and can be quickly accessed via a USB connection. This method offers a significant improvement over previous systems that relied on web APIs, which were often slow and dependent on internet speed. With dedicated software, users can now efficiently retrieve and save tracker data to a PC. Overall, these advancements make the tracker more versatile, reliable, and user-friendly, enhancing the effectiveness of agricultural drone spraying operations.

A. Introduction

In recent years, the integration of Internet of Things (IoT) and precision agriculture has rapidly increased to enhance productivity, reduce manual effort, and optimize resources [1]. One of the most impactful tools in modern agriculture is the use of drones for spraying pesticides and fertilizers. However, monitoring the liquid level in the tank and tracking drone activity over large plantations remains a significant challenge [2], [3]. Traditional data monitoring systems in agriculture often face limitations due to poor network coverage in remote areas, hindering real-time data transmission [4].

The Agriculture Sprayer Drone Tracker addresses these issues by utilizing a LiDAR sensor for liquid level measurement, a sound sensor to detect drone activity, and a u-blox F9P GPS module for accurate position tracking. Data is stored locally on an SD card and retrieved later, eliminating the need for a continuous internet connection [5]. Low-power wide-area network technologies, such as LoRa, offer energy-efficient and reliable communication solutions for IoT and smart grid applications [6], [7].

Low-power consumption is crucial for devices deployed in agricultural environments, especially when they operate in remote locations without easy access to power sources [8]. LoRa technology enables the Main System and Liquid Sensor System to operate in sleep mode, waking only for essential data transmission, thereby optimizing battery life [9]. By focusing on an energy-efficient design, this system ensures that agricultural drones can operate independently over long durations while collecting critical operational data [10].

Furthermore, implementing such technology can significantly improve field management practices, allowing plantation managers to assess drone spray coverage and efficiency based on real operational data, which aligns with the direction of smart farming systems globally [11], [12].

B. Research Method

To develop the Agriculture Sprayer Drone Tracker, we adopt a systematic approach that ensures low power consumption, reliable sensor data, and extended operational longevity. This methodology integrates both the Main System and the Liquid Sensor System. The Main System is responsible for tracking the drone's GPS location, storing data on an SD card, and receiving liquid level data via LoRa communication. The Liquid Sensor System measures the liquid level inside the tank and transmits this data to the Main System.

Traditional methods for drone tracking and liquid level measurement often prove inefficient. Conventional GPS systems primarily track location without monitoring operational status or spraying activity [13]. Traditional liquid level measurement techniques, such as using multiple sensors or cables inside the tank, are prone to errors and necessitate manual monitoring. Moreover, real-time monitoring through web APIs can be unreliable, especially in areas with limited internet connectivity.

To address these challenges, we employ a high-precision u-blox F9P GPS module for accurate drone positioning [3]. For liquid level measurement, we utilize a LiDAR sensor housed in an IP67-rated enclosure, aimed to measure the liquid level of the tank. As the water level decreases, the distance to the surface increases, providing accurate data. A sound sensor detects whether the drone is actively flying , ensuring that data is recorded only during operation [10].

Data is stored locally on an SD card and can later be retrieved via USB for analysis, circumventing issues associated with unreliable internet connections. To achieve low power consumption and prolonged operation, the SX1262 module is selected for its low power consumption and suitability for long-range communication [6]. Lora technology supports deep sleep modes, allowing devices to transmit data intermittently and conserve battery life.

The hardware design comprises two distinct systems: the Main System and the Liquid Sensor System. The Main System includes a microcontroller (STM32), GPS module (u-blox F9P), sound sensor, LoRa module (SX1262), SD card for data storage, and a 3000mAh LiPo battery. The Liquid Sensor System consists of a LiDAR sensor (VL53L0X), a microcontroller, a LoRa module (SX1262), and a 3000mAh LiPo battery. Both systems are designed with efficient power management to minimize energy consumption during periods of inactivity.

The microcontroller in the Main System manages GPS tracking, sound detection, data storage, and LoRa communication with the Liquid Sensor System. The Liquid Sensor System's microcontroller controls the LiDAR sensor, measures the liquid level, and transmits the data to the Main System via LoRa at regular intervals.

Testing focuses on validating the battery life of both systems to ensure they meet the 5-day and 10-day operational requirements, respectively. The accuracy of the GPS and LiDAR sensors is assessed to ensure precise location tracking and liquid level measurement. The effectiveness of the sound sensor in detecting drone operational sounds is also verified. Data integrity is evaluated to confirm that sensor readings are correctly logged on the SD card and can be easily transferred to a PC for analysis.

This comprehensive approach ensures that the Agriculture Sprayer Drone Tracker operates efficiently, reliably, and for extended periods, reducing the need for manual monitoring and enhancing overall operational efficiency [15].

C. Implementation, Testing, Result and Discussion

In this section, we will provide a detailed overview of the implementation process, outline the testing procedures, present the results of the tests conducted, and offer a discussion of the findings related to the development of the Agriculture Sprayer Drone Tracker. This includes the integration of the Main System (GPS, sound sensor, data logging) and the Liquid Sensor System (LiDAR sensor, liquid level measurement).

C.1. Implementation

The implementation process consisted of several crucial steps, including hardware integration, software development, and final system setup for the Agriculture Sprayer Drone Tracker. These steps ensured the efficient operation of both the Main System and the Liquid Sensor System, which work together to track the drone's location and monitor liquid levels in the tank.

1.1 Hardware Setup and Integration

The Main System was built around an STM32 microcontroller, selected for its low power consumption and sufficient processing power to handle GPS, sound sensor, LoRa communication, and SD card operations. The u-blox F9P GPS module was integrated into the system to provide high-accuracy position tracking, which is critical for precise monitoring during spraying. Additionally, a microphone-based sound sensor was included to detect whether the drone was flying and actively spraying. The SX1262 LoRa module was used to establish long-range communication between the Main System and the Liquid Sensor System, while a microSD card was used for storing GPS coordinates, environmental data, and liquid levels. Components integration is shown in Figure 1.

For the Liquid Sensor System, an STM32 microcontroller was chosen for its low power consumption, enabling it to manage the LiDAR sensor, LoRa module, and power management efficiently. The VL53L0X LiDAR sensor was selected for liquid level measurement, as it can accurately detect the distance to the liquid surface. Like the Main System, the Liquid Sensor System also used the SX1262 LoRa module to send data back to the Main System.

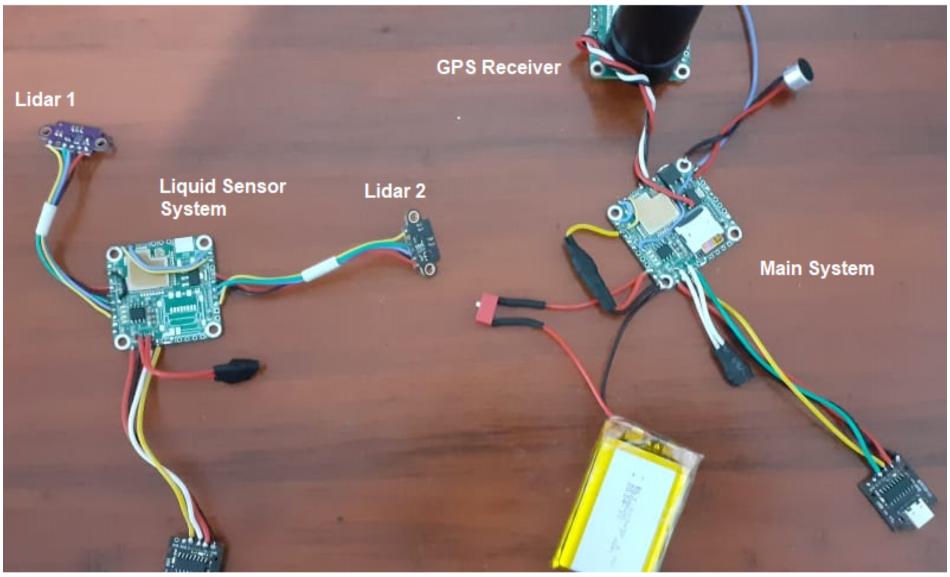

Figure 1. Integration Hardware

1.2 Software Development

The firmware for the Main System was developed to handle GPS data collection, sound sensor monitoring, and data logging on the SD card. The LoRa communication was integrated to facilitate data transfer between the Main System and the Liquid Sensor System. Additionally, the system was programmed to enter low power modes during idle periods to maximize battery life.

The firmware for the Liquid Sensor System was written to manage the LiDAR sensor, calculate the liquid level, and send the data back to the Main System via LoRa at specified intervals.

1.3 Testing and Calibration

The testing phase began with hardware validation, where each component, such as the GPS, sound sensor, LiDAR sensor, LoRa modules, and SD card, was tested individually to ensure they were functioning correctly. Once confirmed, the Main System and Liquid Sensor System were connected, and communication was tested to ensure reliable data transfer. Battery life was also tested by running both systems in operational environments and tracking their performance over time.

C.2. Testing

2.1 GPS Accuracy Testing

The u-blox F9P GPS module was tested in various outdoor environments to measure its accuracy. The GPS data was compared, and the system consistently delivered sub-meter accuracy, ensuring that the drone's location could be tracked precisely during spraying operations. This level of accuracy is essential in agricultural applications, where precise tracking is required to ensure that the drone performs spraying tasks in the correct locations.

2.2 Liquid Level Sensor Testing

The LiDAR sensor was tested by measuring the liquid level in the drone's tank. The readings from the sensor were cross-checked with manually measured liquid levels to confirm accuracy. The results showed that the LiDAR sensor provided consistent and reliable measurements with an error margin of less than 2 cm. The sensor was also able to provide real-time updates, allowing for continuous monitoring of the liquid level during drone operations.

2.3 Sound Sensor Testing

The sound sensor was tested to ensure that it could detect the operational sounds of the drone during flight. The sensor successfully identified when the drone was actively flying, distinguishing between idle and active modes. The sound sensor was sensitive enough to detect drone operations from up to 1 meters away, and its performance was reliable across different environmental noise conditions.

2.4 Battery Life Testing

Battery life was a critical component of the system, as both the Main System and the Liquid Sensor System relied on their internal batteries for continuous operation. The Main System operated for approximately 5 days on a 3000mAh battery, while the Liquid Sensor System lasted for about 10 days on the same battery size. These results met or exceeded the design specifications, ensuring that the systems could function in the field for the required duration without requiring frequent recharging.

C.3. Results

The results of the testing phase demonstrated that the Agriculture Sprayer Drone Tracker met the performance expectations. The GPS module consistently provided sub-meter accuracy, which is suitable for precise monitoring of the drone's location during spraying activities. The LiDAR sensor accurately measured the liquid levels in the tank, providing real-time data that could be used to track the spraying operation. The sound sensor reliably detected the drone's operational state, ensuring that data was recorded only during actual spraying activities.

In terms of battery life, the Main System operated for approximately 5 days, and the Liquid Sensor System lasted for 10 days on a 3000mAh battery, which aligned with the system's design objectives. The LoRa modules enabled reliable communication between the two systems, even at long range, and the SD card provided efficient local storage, eliminating the need for constant internet connectivity. Final Result is shown in Figure 2.

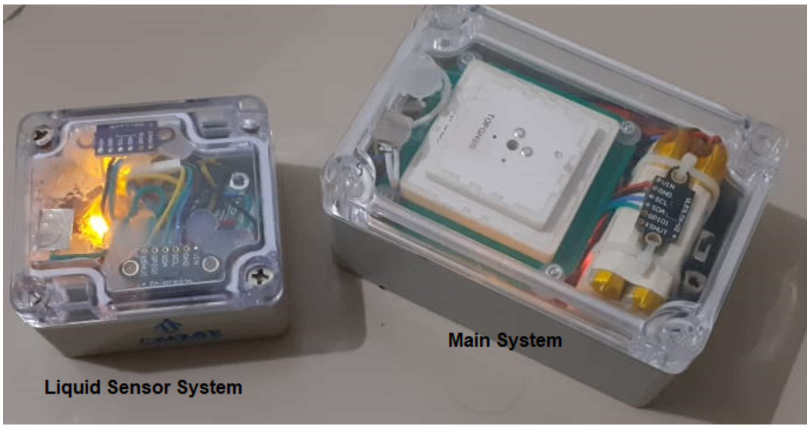

Figure 2. Final Result

C.4. Discussion

The implementation of the Agriculture Sprayer Drone Tracker system achieved the intended goals, providing accurate GPS tracking, reliable liquid level measurement, and sound detection for drone operations. The integration of the LiDAR sensor for liquid level measurement proved to be the most effective method, providing consistent and accurate readings with minimal error.

The battery life testing was successful, with both the Main System and Liquid Sensor System operating within the desired time frame on a single 3000mAh battery. The use of SX1262 LoRa modules allowed for low-power, long-range communication between the two systems, which is crucial for applicationsthat need reability.

One of the key advantages of this system is the ability to save data locally on the SD card and later retrieve it via a USB cable, which eliminates the need for constant internet access. This feature makes the system more versatile and adaptable to various environments, including remote areas where internet connectivity may be slow or nonexistent.

In conclusion, the Agriculture Sprayer Drone Tracker provides a reliable, low-power solution for tracking drone operations and monitoring liquid levels in real-time. It offers significant advantages over traditional systems, including enhanced accuracy, efficiency, and battery life, making it an excellent choice for agricultural applications that require constant monitoring of drone activities.

D. Conclusion

The Agriculture Sprayer Drone Tracker system successfully addresses key challenges in agricultural drone monitoring by providing a robust, reliable, and low-power solution for tracking both drone location and liquid levels in the tank. The integration of GPS tracking, sound sensors, and LiDAR-based liquid level measurement allows for comprehensive monitoring of drone operations, ensuring that spraying tasks are performed accurately and efficiently.

Through the use of LoRa communication, the system achieves low-power, reliable data transmission between the Main System and the Liquid Sensor System, ensuring that both systems can operate efficiently without consuming excessive power. This communication mechanism provides a dependable connection between the two systems, which is crucial for maintaining performance in field conditions where long-lasting battery life is essential.

The Main System and Liquid Sensor System both demonstrate impressive battery longevity, with the Liquid Sensor System lasting up to 10 days and the Main System operating for 5 days on a 3000mAh battery. These results align with the goal of achieving extended operational times, minimizing the need for frequent recharging or maintenance.

The decision to store data on an SD card and retrieve it later via USB cable adds flexibility and ease of use, particularly in areas with unreliable internet connectivity. By eliminating the dependency on real-time internet access, the system offers enhanced adaptability and usability in diverse environmental conditions.

In conclusion, this system provides a significant advancement over traditional methods of monitoring drone operations in agricultural applications. It not only tracks the drone’s location but also provides insights into the liquid level in the tank, eliminating the need for human intervention to verify spraying accuracy. The system’s versatility, low power consumption, and reliability make it a valuable tool for enhancing the efficiency and effectiveness of drone-assisted agricultural spraying tasks. The successful implementation of this technology demonstrates its potential for widespread adoption in precision agriculture.

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