Drone System: Technical Working Principle and Methodology

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1. Overview of Drone Operations

The updated drone is a multirotor system designed for aerial surveillance, environmental data collection, crop monitoring, and precision spraying operations. With enhanced components such as multispectral and thermal cameras, it supports advanced agricultural analysis and spraying capabilities. This section outlines the working principles and methodologies covering flight control, sensor integration, spraying mechanism, and data collection.

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2. Flight Control System

The drone's flight is managed by a **Pixhawk PX4 Flight Controller**, which processes sensor inputs and controls the drone's altitude, orientation, and movement.

- **Flight Controller**: The **Pixhawk PX4** controls flight operations, including stabilization, navigation, and mission execution using the **Ardupilot** software.
- **GPS Navigation**: The **Ublox NEO-M8N GPS** provides precise positioning, enabling the drone to follow pre-programmed flight paths. GPS data is combined with the **BMP280 atmospheric pressure sensor** for accurate altitude control.
- **Motor and Propeller Control**: The drone uses **3508 700KV BLDC motors** paired with **Gemfan 15x6 propellers** to generate the required lift. **T-Motor F60A ESCs** control motor speeds for stable flight and maneuvering.
- **Power Supply**: The drone is powered by a **Tattu 6S 22000mAh 22.2V LiPo battery**. Power is distributed to all electronic components through a **Matek Systems PDB-XT90** board.

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3. Sensor Integration and Environmental Monitoring

The updated drone features an array of sensors to gather environmental data, assist in autonomous flight, and monitor agricultural conditions.

- **Temperature & Humidity Sensor (DHT22)**: Measures atmospheric conditions, providing real-time weather data for safe flight operations.
- **Atmospheric Pressure Sensor (BMP280)**: Supplies altitude and pressure information for stabilization, improving flight accuracy.
- **CO2 Sensor (MH-Z19)**: Monitors carbon dioxide levels in the air, helpful for assessing air quality and environmental conditions.
- **Ultrasonic Sensor (HC-SR04)**: Provides obstacle detection and landing assistance by measuring the distance between the drone and the ground or objects.

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4. Camera Systems and Data Collection

The drone is equipped with multiple cameras for capturing RGB, thermal, and multispectral data essential for agricultural analysis.

- **RGB Cameras (x5)**: Five **Raspberry Pi Camera Module 3 NoIR** capture high-resolution color images for visual inspections, aerial photography, and crop monitoring.
- **Thermal Camera (Waveshare MLX90640)**: Detects temperature variations across the field to identify heat stress, water content, and potential equipment overheating.
- **Multispectral Camera (DIY)**: A standard RGB camera modified with **Roscolux filters** (Near-Infrared, Red, Red Edge, and Green) captures specific wavelengths, allowing the calculation of vegetation indices such as **NDVI**, **NDWI**, **LAI, RE NDVI, GNDVI** and **Chlorophyll Index (CI)** for plant health monitoring.

   a. Near Infrared Filter [700-1000nm] Model – Hoya R72 Infrared Filter
   b. Red Filter [620-750nm] Model – Schott RG630 Long-Pass Filter + Thorlabs FELH0750/Schott BG40 IR-Cut Filter (Combination)
   c. Red Edge Filter [700-750nm] Model – Schott RG715 Long-Pass Filter + Thorlabs FELH0750/Schott BG40 IR-Cut Filter (Combination)
   d. Green Filter [500-600nm] Model – Wratten 58 Green Filter

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5. Spraying Mechanism

The drone features a **10L HDPE tank** for storing liquid fertilizers or pesticides and is equipped with **TeeJet AIXR 11004-VP** sprayer nozzles for precision spraying.

- **Tank and Sprayer**: The **10L HDPE tank** holds liquid for spraying. The **TeeJet AIXR 11004-VP nozzles** provide consistent and even distribution of the liquid across the targeted area, optimizing spraying coverage while minimizing wastage.
- **Spraying Control**: The spraying process is controlled via the **Ground Station Interface** software, allowing the operator to manage the timing and coverage area during flight.

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6. Data Transmission and Communication

The drone is equipped with **long-range LoRa communication** for real-time data transmission and remote control.

- **LoRa Communication Module (RFM95)**: Enables long-range data transmission between the drone and ground station over distances of up to 15 km, even in remote agricultural areas.
- **Raspberry Pi Microcontroller**: Functions as the central hub, processing sensor data and managing camera operations. It interacts with the flight controller, based on the predefined control algorithms.

<u>Post-Flight Data Analysis</u>

After each flight, the collected data is analyzed using various deep learning models for precision agriculture applications.

1. **Crop Health and Vegetation Analysis**
   - **Working Principle**: The multispectral data is used to calculate vegetation indices like **NDVI** and **Chlorophyll Index** to assess the health and vitality of crops. The analysis is carried out using machine learning models to detect any anomalies in crop health.
   - **Output**: The system generates a report detailing areas of concern, such as nutrient deficiencies or pest infestations.
2. **Thermal Analysis for Plant Stress**
   - **Working Principle**: Data from the thermal camera is analyzed to detect temperature anomalies in plants, which could indicate water stress or disease.
   - **Output**: The analysis provides insights into irrigation needs and early detection of crop diseases.
3. **Yield Estimation**
   - **Working Principle**: The RGB camera data is processed to count flowers or fruits, providing an estimate of crop yield. Image classification techniques based on convolutional neural networks (CNNs) are employed to recognize and count the relevant objects.
   - **Output**: A yield forecast is generated to assist in production planning and inventory management.
4. **Precision Spraying Analytics**
   - **Working Principle**: Using sensor data, the drone's spraying pattern is optimized to ensure even distribution of pesticides or fertilizers. The system uses real-time data to adjust the sprayer nozzles' flow rate based on crop density and area coverage.
   - **Output**: Detailed feedback on spraying efficiency and area coverage is provided, allowing for adjustments in future missions.

Conclusion

The new drone operates autonomously with GPS-based navigation and advanced sensor integration for environmental monitoring, precision agriculture, and efficient spraying. The data collected is processed through AI-driven models to provide actionable insights into crop health, yield estimation, and disease detection. This enhanced drone system offers a powerful tool for modern agricultural practices, improving efficiency, precision, and sustainability.