Chapter 6 DRONES FOR HORTICULTURE

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Introduction

Drones are referred commonly with alternate names such as

- Unmanned Aerial Vehicles (UAVs)
- Unmanned Aircraft Systems
- Uncrewed Aircraft Systems
- Unpiloted Aircraft
- Unmanned Aerial Systems (UAS)
- Remotely Piloted Aircraft System (RPAS)

The term drone has various meaning on different contexts such as,

- Biological context, a drone is a male bee
- Sound context, a drone is a monotonous, sustained low-pitched noise that lacks variation or melody

Drone applications encompass numerous areas, including, reconnaissance, agricultural operations (spraying, seeding, broadcasting of fertilizers and harvesting etc), surveillance, mine rescue operations, and so on.

Different types of drones based on rotor classification include (Hassanalian & Abdelkefi, 2017),

1. Fixed wing
2. Single rotor
3. Hybrid drone
4. Multi-rotor

Key features of various drones are as follows

- Fixed wing drone are well-known for its endurance
- Helicopters/multirotors have the benefit of Vertical Takeoff and Landing (VTOL) and hovering
- Quad-rotor cross configuration (Pair of opposite rotors rotating counter-clockwise and the other pair rotating clockwise) can move quickly and easily, both physically and metaphorically

These days' researchers aim to unite the benefit of multi-rotor wing and fixed drones

Different types of drones based on power include

1. Electric Drones

2. Petrol-Powered Drones
3. Gas-Powered Drones
4. Solar-Powered Drones
5. Hydrogen fuel cell drones
6. Tethered Drones
7. Hybrid Drones

Fig.1 Battery Operated Drone (Hexacopter) and Petrol powered drone (Quadcopter)

Fig.2 Solar Powered Drone

Source: www.droneassemble.com

Fig.3 Hybrid drone (VTOL)

Source: www.droneassemble.com

Fig.4 Tethered drones

Source: www.dragonflypictures.com

Size of the drones

Size of drone varies from "nano" to "mega" based on the weight of drones.

1. Nano: less than 250 grams
2. Mini: 250 grams to 2 kilograms
3. Small: 2 kilograms to 25 kilograms
4. Medium: 25 kilograms and 150 kilograms
5. Large: more than 150 kilograms

Also, Featherweight drones under the nano category may have a weight of 11 grams.

According to length the drones may be classified as follows,

1. Very small drones: 150mm
2. Small drones: Up to 300mm
3. Medium drones: 300-1200mm
4. Large drones: More than 1200 mm

US military classification of drones based on their travel range and their endurance in the air, as follows

1. Very close-range UAVs (5 km range and 20 to 45 minutes endurance time)
2. Close-range UAVs (50 km range and 1 to 6 hours endurance time)
3. Short-range UAVs (150 km or longer km range and 8 to 12 hours endurance time)
4. Mid-range UAVs (650 km range and 24 hours endurance time)
5. Endurance UAVs (300 km range and 36 hours endurance time)

Working of a drone: Aerodynamics

In drone aerodynamics, lift and drag are crucial forces that determine the aircraft's performance. Lift is generated by the drone's wings or rotors, providing the necessary upward force to counteract gravity and keep the drone airborne. Drag, on the other hand, is the resistance encountered as the drone moves through the air, opposing its forward motion. Engineers carefully balance these forces to optimize the drone's efficiency, manuevarability, and overall flight characteristics. Achieving the right lift-to-drag ratio, i.e. ensuring the total thrust force remains equal to the weight of the drone is crucial for maintaining a stable and controlled flight.

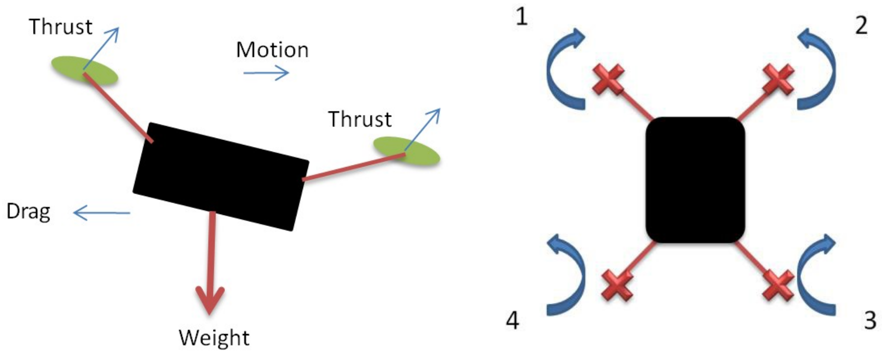

Fig.5 Rotor configuration and Force Representation of Drone

The symmetrical design of drones allows it to treat any side as the front, simplifying control and navigation. As shown in fig.5, Rotors are paired in sets with opposite directions of rotation (clockwise and counter clockwise) to cancel out angular momentum and maintain a net angular momentum of zero, allowing the drone to hover. To induce rotation (yaw), the spin of rotors 1 and 3 is decreased, while that of rotors 2 and 4 is increased. Increasing the rates of rotors 3 and 4 while decreasing those of rotors 1 and 2 maintains equal thrust force, keeping the drone at the same vertical position, and this asymmetrical thrust distribution induces a forward tilt. Similarly the rearward and sideward movements takes place.

Components of a drone

- BLDC Motors
- Flight Control System
- DGPS
- Ground Control Station
- Power system
- Sensors
- Landing gear

BLDC Motors

Brush-Less DC (BLDC) motors are a vital component in drone hardware, offering advantages like increased efficiency, reliability, and longer lifespan compared to traditional brushed motors. These motors employ electronic commutation, eliminating the need for physical brushes, reducing friction and wear. BLDC motors contribute to the drones' lightweight design and improved aerodynamics, enabling better agility and longer flight times. The precise control afforded by BLDC motors enhances stability and responsiveness, making them an ideal choice for various drone applications, from hobbyist quadcopters to professional aerial photography platforms.

Flight control

Drone flight controllers, also called as Flight Control Systems (FCS) are crucial components that manage the stability and navigation of unmanned aerial vehicles. Key components integrated with these controllers are on-board sensors which include gyroscopes, accelerometers, and barometers, and they work together to provide accurate orientation, velocity, and altitude data (Silvagni et al., 2017). Integrated processors handle data fusion and execute flight algorithms.

The roll, yaw and up-thrust, pitch actions are controlled by altering the thrusts of the rotors by means of Pulse Width Modulation (PWM) to give the required action. Real-Time Operating System (RTOS) facilitates task schedule preparation, organization of accessible resources such as memory, inter-task communication, and power utilization.

Localization

For accurate localization, drones extensively use Differential Global Positioning System (DGPS). Some cases of drone applications are GPS denied, thus currently, laser scanners, vision sensors, and the IMU are the alternative position sensors used for drone self-localisation.

Ground Control Station (GCS) comprises of software and hardware essential for drone remote control. Hardware, like joysticks, smart phones takes the pilot's command which is transmitted to the drone through radio transmitter. GCS collects telemetry data and provides it on the GCS user interface (Carlson and Rysgaard, 2018). Data flow between GCS and drone on a mission takes place by communication networking.

Path planning

Path planning is a key aspect of autonomous type of navigation. It generates a set of waypoints or path which drone follows considering the physical and environmental constraints of the drone to accomplish collision free flight (Chen et al*.,* 2018). Implementation of path planning aimed at finding the optimum path to maximize the value of gathered sensing data and to minimize flight time, energy use, and operational risks. Quite a few algorithms for quantifying distances to obstacles and calculations of the drone's path are inclusive (Silva et al*.,* 2017).

Power system

The flight time of a drone is directly influenced by the battery's capacity and the power requirements of the drone's components. Lithium-Polymer (LiPo) is the most common type of battery used in drones. LiPo battery offers a high energy density, providing a good balance between weight and capacity. Drones function on specific voltage requirements. Some common voltage levels include 3.7V, 7.4V, 11.1V, and 14.8V and 24.1 V. Drone batteries typically use specialized chargers to charge themselves. Proper care and maintenance of drone batteries are essential for ensuring safe and reliable operations.

Sensors

The combination of following sensors allows drones to work autonomously, navigate difficult environments, and perform a broad range of tasks.

- Barometer: Estimate drone's altitude
- Compass/Magnetometer: Estimate drone's orientation
- Inertial Measurement Unit (accelerometers and gyroscopes): Estimate drone's velocity, acceleration, and orientation
- Proximity Sensors (Ultrasonic and infrared sensors): Obstacle detection and avoidance in drones
- LiDaR (Light Detection and Ranging): Estimate distances

- Radar: Long-range object detection in drones
- Terrain Profiling Sensors: Estimate slope, roughness, and other characteristics of the terrain
- Load Sensors: Monitor the payload
- Image Sensors: Capturing visual data (standard photography, videography etc)

Landing gear

Landing gear serves as an essential component in drone design, providing support during takeoff, landing, and while on the ground. It typically includes structural elements and shock absorbers to absorb the impact of landings and ensure a smooth touchdown. The design of landing gear varies based on the types of drone and its attachment. Effective landing gear contributes to the overall safety and operational capabilities of an aircraft by mitigating forces during landings and supporting ground maneuvers.

Various attachments to drones

Various attachments for drones in order to accomplish variety of tasks include,

- Agricultural sprayers
- Lighting Systems
- Manipulator Arms or Grippers
- Net Guns or Capture Mechanisms
- Cutting tools
- Geotagging and GPS Devices
- Cameras and Imaging Devices
- Communication Equipment
- Sensors

Agricultural Applications of Drones

- Crop monitoring (Gokool et al., 2023)
- Soil mapping (Rathinavel et al., 2023)
- Yield estimation (Tanut et al., 2021)
- Insect Control (Kakutani et al., 2021)
- Seed bombing (Saikia et al., 2023)
- Seed/fertilizer broadcasting (Marzuki et al., 2021; Rathinavel et al., 2023)
- Spraying (Chemicals on crops/Paints on protected houses) (Shahrooz et al., 2020)
- Pollinations Assistance (Diaz et al., 2021)
- Coconut/fruit harvesting (Rathinavel et al., 2023)
- Bird scarer (Mohamed et al., 2020)

Farm Drones: Indian context

The Government of India has taken a significant step in agricultural research by approving the use of drones, initially for the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) in Hyderabad. This move, regulated by the Ministry of Civil Aviation (MoCA) and Directorate General of Civil Aviation (DGCA), signifies a shift towards modern technology in the farming sector.

To ensure responsible drone usage, the government has set specific criteria. Individuals operating drones must be between 18 and 65 years old, registered, and issued a Unique Identification Number (UIN). Moreover, only those holding a remote pilot license (RPL) and enlisted on the digital sky platform are authorized to operate drones, emphasizing the importance of skilled and certified individuals in this field.

Acknowledging the environmental impact of drone activities, the International Organization for Standardization (ISO) has developed standards for environmental requirements and field testing of drone spraying. Concurrently, the Bureau of Indian Standards (BIS) is actively engaged in the ongoing development of standards, reflecting a commitment to refining and advancing the drone technology landscape in the agricultural sector. These developments showcase a holistic approach by the Indian government to leverage cutting-edge technology for agricultural innovation while ensuring safety, compliance, and environmental sustainability.

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