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DRONE TECHNOLOGY

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ABSTRACT

This article talks about drones in Indian agriculture which has gained significant attention in recent years due to their potential to revolutionize the way crops are monitored and managed. Drones, also known as unmanned aerial vehicles (UAVs), are being increasingly used in Indian agriculture for various purposes, such as crop health monitoring, yield estimation, soil analysis, and irrigation management.

One of the key advantages of using drones in Indian agriculture is their ability to cover large areas quickly and efficiently, which allows farmers to gather detailed information about their crops in a shorter amount of time. This information can be used to identify areas that require attention and optimize crop management strategies.

Drones equipped with multispectral sensors can capture high-resolution images of crops, which can be used to analyze plant health and detect early signs of disease or nutrient deficiencies. This information can help farmers take proactive measures to address these issues before they become more severe and impact crop yields.

Drones can also be used for precision agriculture, which involves using data and technology to optimize crop production while minimizing inputs such as water, fertilizer, and pesticides. By using drones to monitor crops, farmers can identify areas that require more or less inputs, which can help reduce costs and improve yields.

In addition to crop monitoring, drones can also be used for mapping and surveying land, which can help farmers make better decisions about irrigation and soil management. For example, drones can be used to create detailed maps of fields, which can help farmers identify areas with different soil types and moisture levels. This information can be used to develop customized irrigation and fertilization plans that are tailored to the specific needs of each area.

However, the use of drones in Indian agriculture also comes with some challenges. One of the main challenges is the cost of the technology, which can be prohibitively expensive for many farmers. Additionally, there are regulatory challenges related to the use of drones, as the Indian government has strict rules governing their use.

Overall, the use of drones in Indian agriculture has the potential to improve crop management, increase yields, and reduce costs. However, there are challenges that need to be addressed before widespread adoption can occur.

Keywords - Drone, Drone Technology, Technology of Drones, Technology used for Drones, Technology behind Drones, Technology used inside Drones, Technical inside of Drones, Technical aspect of Drones

INTRODUCTION

Drones are also popular as unmanned aerial vehicles (UAVs), in agriculture is a relatively recent development, but the concept of using remote sensing technology to monitor crops and land has been around for several decades. Here is a brief history of agricultural drones:

In the early 1980s, researchers at the University of Nebraska began experimenting with remote sensing technology to monitor crops. They used small planes equipped with cameras and sensors to collect data on crop health, water use, and other factors.

In the 1990s, the advent of satellite imagery made remote sensing technology more accessible to farmers. Companies like Landsat and SPOT began offering satellite imagery for agriculture, which allowed farmers to monitor their crops from above and make informed decisions about irrigation, fertilization, and other practices.

In the early 2000s, the first commercially available drones began to appear on the market. These early drones were primarily used for military purposes, but hobbyists and researchers also began experimenting with them.
In 2011, the Federal Aviation Administration (FAA) issued its first permit for agricultural drone use to the Yamaha Motor Company, which was conducting crop spraying trials in California.

In 2012, Precision Hawk, a drone manufacturer and data analytics company, was founded. The company quickly became a leader in the agriculture drone market, offering drones and software for crop monitoring and analysis.

In 2015, the FAA issued new regulations allowing for commercial drone use in the United States. This opened up new opportunities for farmers and companies to use drones for agriculture. Since then, the use of drones in agriculture has continued to grow. Drones are now used for a wide range of applications, including crop mapping, plant counting, yield estimation, and crop spraying.

Overall, the history of agricultural drones is relatively short, but the technology has rapidly evolved and become an important tool for modern farmers and agribusinesses.

RESEARCH, DEVELOPMENT & TECHNOLOGY

The development of drones includes many key components:

- **Design and manufacturing:** Drones can be designed and built for various purposes, from hobbyist use to military applications. The design process includes selecting the appropriate materials, determining the size and shape of the aircraft, and designing the propulsion system and control mechanisms.
- **Navigation and control:** Drones use a variety of sensors to navigate and control their flight, including GPS, accelerometers, gyroscopes, and magnetometers. The pilot or autonomous system can use this data to control the drone's speed, altitude, direction, and other flight parameters.
- **Communication:** Drones require a means of communication with the pilot or autonomous system to receive commands and transmit data. This is typically done using radio frequency (RF) communication, which allows for real-time control and data transmission.
- **Payload:** Drones can be equipped with various payloads depending on their intended use, such as cameras for aerial photography, sensors for environmental monitoring, or weapons for military applications.
- **Safety and regulation:** Drones must operate safely and comply with regulations set by governing bodies. This includes adhering to airspace restrictions, obtaining necessary permits and certifications, and implementing safety features such as collision avoidance systems.

Following Equipments, Techniques and Technologies contributed in drone development:

- **CAD (Computer Aided Design) Software:** It's used to design and model the drone's various components, including the frame, motors, and propellers. It allows for precise measurements and specifications, making it easier to manufacture the drone.
- **3 Dimensional Printing:** 3 Dimensional printing process creates three-dimensional objects with layering material on top. This technology is used in drone manufacturing to create prototypes, test designs, and manufacture small components.
- **CNC Machines:** CNC (Computer Numerical Control) machines are used in drone manufacturing to create precise cuts and shapes for the drone's components. These machines can be programmed to cut and shape materials like aluminum, carbon fiber, and plastic.
- **Lithium Polymer (LiPo) Batteries:** LiPo batteries are lightweight and have a high energy density, making them ideal for use in drones. They provide the necessary power to keep the drone flying.
- **Brushless Motors:** Brushless motors are used in drones because they are more efficient and reliable than traditional brushed motors. They provide the power needed to keep the propellers spinning and the drone in the air.
- **GPS Technology:** GPS technology is used in drones to provide accurate positioning and navigation. It allows the drone to fly to specific locations and to return to its starting point if needed.
- **Radio Communication:** Radio communication technology is used to control the drone and to receive data and video transmissions from the drone. This technology allows the drone to be controlled from a remote location.
- **Sensors:** Drones are equipped with various sensors, including accelerometers, gyroscopes, and barometers that help the drone maintain stability and altitude. They also provide data that can be used to improve the drone's performance. Overall, these tools and technologies are essential for the design, manufacturing, and operation of drones. They enable the production of highly specialized and sophisticated drones that can perform a wide range of tasks, from aerial photography and videography to surveying and mapping.

Main 4 types of Drone Equipments

Drone monitoring equipment refers to the tools and technologies used to track and monitor the operational activity of drones which is well-known as unmanned aerial vehicles (UAVs). Here are some examples of drone monitoring equipment:

- **Acoustic Sensors (Microphone):** Acoustic sensors can be used to detect the sound signature of drones. These sensors can be used to locate the drone and determine its flight path.
- **Camera Systems:** Camera systems can be used to visually monitor drones in real-time. These systems can capture images and videos of the drone, its flight path, and its surrounding area.
- **GPS Tracking Systems:** GPS tracking systems can be used to track the location of drones. These systems can also be used to monitor the drone's flight path and speed.
- **Radio Frequency (RF) Detectors:** RF detectors can be used to detect the radio signals used by drones to communicate with their operators. These systems can be used to locate the drone and determine its flight path.
- **Anti-drone systems:** Anti-drone systems are designed to prevent drones from flying in restricted airspace or to force them to land safely. These systems can use technologies such as radio frequency jammers, net guns, or lasers to disable or capture the drone.
- **Drone detection software:** Drone detection software uses algorithms to analyze data from various sensors and cameras to detect the presence of drones. These systems can provide early warning of drone activity and help prevent security breaches or unauthorized surveillance.

Pros: It's very low-cost with no license requirements. which detects and tracks multiple drones and controllers, Few of them are capable enough to triangulate the position of the drones and controllers.
Cons: Tracking & Locating is not always possible, difficult to detect autonomous drones and congested HF small range drones which is not so efficient.

1) Acoustic Sensors (Microphone)

Use of drones tremendously increased in recent years which required us to think about severe safety and privacy issues. Using microphone arrays for drone detection is one of the successful techniques. Though not very successful due to synchronization, complexity, and data management issues, Microphone use is quite difficult to service large-scale applications. However DAS (Distributed Acoustic Sensors) with dioptrics has proven significance for tracking vibrations of long distances. It lowers the sensitivity for weak airborne acoustics. Based on experts' knowledge and study the first functional use of fiber optic acoustic sensor was for the drones surveillance.

The FOAS (Fiber Optic Acoustic Sensors) has been significantly used in detecting drone sound, While DAS has extremely high capacity to measure 101.21 re responsiveness. 1 rad/µPa and to recover speech with high fidelity using optical fiber. By providing synchronization and centralized signal processing only DAS has queried a number of FOAS for the long distances. We use FOASs as a sensor array to show off the field test for drone identification and localization while DAS to remotely capture the airborne sound. Waveforms and Spectral characteristics are easy to identify from the drone sound. Precise drone localization can be accomplished by Root Mean Square Error (RMSE) of 1.47 degrees using acoustic field mapping and data fusion. An acoustic sensor is a device that can detect, measure, and analyze sound waves of the environment by converting sound waves into electrical signals processing by the electronic devices.

Acoustic sensors are used in various applications such as in the fields of engineering, medicine, military, and entertainment. For example, in engineering, acoustic sensors are used to monitor vibrations and detect anomalies in machines and structures. In medicine, acoustic sensors are used to diagnose and treat various health conditions, such as hearing loss and sleep apnea. In military applications, acoustic sensors can be used to detect the presence and location of enemy troops and vehicles. There are different types of acoustic sensors, such as microphones, hydrophones, and accelerometers, which are designed to detect different types of sound waves. Microphones are commonly used to detect airborne sound waves, while hydrophones are used to detect underwater sound waves. Accelerometers are used to detect mechanical vibrations and convert them into electrical signals.

So Many configured arrays have been researched including the small opening circular array, the L-shaped planar array, a tetrahedral array and widely distributed small arrays. By analyzing the acoustic signals received from the microphones, a range of applications were used to introduce object classification, target tracking and SLAM (Simultaneous Localization and Mapping). For the UAV platforms' efficient development these systems became a very efficient tool for the safety and security, therefore accurate location and detection of long distance UAVs are important.

UAVs passive detection and tracking has been made possible by their acoustic signature. Mainly two types of standard processing methods are used to estimate flight parameters, based on the spectral components of the acoustic signal. A narrow band processing method is used to estimate the flight parameters to produce powerful harmonic sound for propeller driven aircraft and helicopters. Motion makes the recognition of the aircraft's instant frequency, Doppler shifted acoustic signature is the foundation of the strategy. However, a broadband processing method accounts for the temporal variation between multiple microphone pairs used for time delays to deal with UAVs (Unmanned Aerial Vehicles). The broad band approach is more adaptable than the narrow band approach which does not omit strong narrow band waves or fixed harmonic frequencies, the best way to accurately estimate flight parameters is used by both approaches when a UAV passes over the array, In fact, many researchers have reported detection range of more than 2 kilometers by implementing such methods for aircraft and UAV (Unmanned Aerial Vehicles). On other hand UAV is far better from the microphones, its weak signal makes it difficult for both broad band and narrow band approaches to produce reliable results in comparison to the noise. After detailed study of highly desired acoustic signals it presents UAV detection, localization, and tracking challenges.

Similar signal conditions exist in nature. Acoustic signals can be converted into "images" same as the visual scenes by using spectrograms and correlograms, For example, spread the luminance on naturally lit scenes to cover-up a wide dynamic area, however dark regions details are covered in noise. Same way Insect Visual System, such as hoverfly, it is one of the proven powerful information capturing systems. As a result, we can use time frequency analysis to transform 1 dimensional acoustic signals into 2 dimensional images using these conventional methods. Detected Acoustic signals are typically depicted as spectrograms with the frequency of harmonics taken out in the narrow band approach. Time delays can be captured from correlograms when using the broadband techniques. In this way, Vision processing techniques are useful in analyzing the acoustic signal of interest, to take the form of harmonics or correlation in 2 dimensional arrays or matrices.

Acoustic sensors are devices that convert sound waves into electrical signals that can be processed by electronic circuits. The most common types of acoustic sensors are microphones, which are used in a variety of applications, including audio recording, voice communication, and speech recognition.

The formula for the output voltage of a microphone is:

$$V = S \times P$$

Where V = output voltage, S = Sensitivity of the microphone and P = SPL (Sound Pressure Level) in decibels (dB).

The microphone sensitivity measures its efficiency in converting sound waves into electrical signals. It is usually expressed in volts per Pascal (V/Pa), which is a measure of the output voltage per unit of sound pressure.

The SPL (Sound Pressure Level) measures the intensity of sound waves. Depicted in decibels (dB) and mentioned as:

$$SPL = 20 \log (P/P0)$$

Where P = SP (Sound Pressure) and P0 = Reference Sound Pressure, is usually taken to be 20 microPascals (μPa).

In short, Formula to output the voltage of an Acoustic Sensor microphone, is

$$V = S \times P$$

Where S = Sensitivity of the Sensor and P = Sound Pressure Level in decibels.

Overall, Acoustic Sensors are important tools for detecting and analyzing sound waves in different applications, or monitor drone machinery to enhance entertainment experiences.

Pros: Detects all drones at close range, including those that operate autonomously (without (RF emissions)). Detects cluttered drones that other technologies struggle with. Filling gap between areas outside the field view of other sensors. Instant mobile friendly and ready to use.
Cons: Does not perform well in noisy atmosphere and covers small area of distance (up to 300-500m)

2) Camera Systems

Camera systems are electronic devices that detect light and convert it into an electrical signal that can be processed by a computer or other electronic device. They are used in a wide range of applications, from automatic lighting systems to digital cameras. There are several different types of Camera system, each with its own characteristics and applications:

- **Photoresistors:** These are simple sensors that change their resistance in response to changes in light levels. They are often used in basic applications such as nightlights.
- **Photodiodes:** These sensors are made of semiconductor materials that generate a current when exposed to light. They are commonly used in electronic circuits as light-sensitive switches.
- **Phototransistors:** These sensors are similar to photodiodes, but they have a built-in amplifier that allows them to detect very low levels of light.
- **CCD sensors:** These are used in digital cameras to capture images. They are made up of a grid of light-sensitive pixels that generate an electrical charge when exposed to light.
- **CMOS sensors:** These are another type of image sensor used in digital cameras. They use a different type of circuitry than CCD sensors, which makes them more power-efficient.

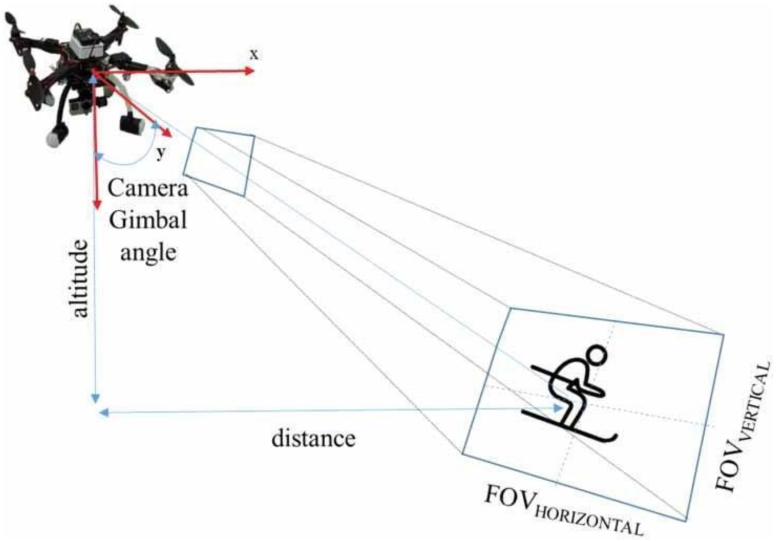

Fig. 2.1 operational model

In recent years, a few features of sophisticated commercial drones have drawn growing attention. Little drones have a higher chance of being used for unauthorized activities because of their capacity to transport payloads without violating ground security. For the purpose of preventing security lapses like this, drone tracking and surveillance are essential.

With complex backgrounds, small drones and birds might seem similar, making it challenging to distinguish drones in surveillance footage. A very difficult and tiresome process is manual surveillance and drone detection. To have a backup plan in case something goes wrong is always a good idea.

On each video frame, the five FMO parameters are calculated. Before classifying data using a random forest classifier, features are ranked to determine which ones are important for drone identification. The Drone v/s Bird Detection Provocation at IEEE AVSS 2021 dataset is given by the WOSDSDCT (Workshop on Small Drone Surveillance, Detection and Counteraction Techniques) supported by the SSC (Safe Shore Consortium), for assessing suggested method effectively.

The suggested method has accuracy of 94.15% on an average with the sensitivity rate of 96.69% to identify drones with DP (Drone Present) v/s. NDNBP (neither drone nor bird present) with accuracy rate of 93.60% and sensitivity rate of 96.20% to identify drones with BBDP (both bird and drone present) v/s. NDNBP (neither drone nor bird present) with accuracy rate of 92% with sensitivity rate of 95% to identify drones with BP (bird present) v/s. BBDP (not bird and drone present) v/s. NDNBP (neither drone nor bird present).

Not a single formula for drone camera systems, as the specific components and specifications of a drone's camera system will be dependent on a variety of factors including intended use of the drones, Drone size and weight with the desired image or video quality. However, few key factors should be considered while designing a drone camera system.

- **Sensor size:** The size of the camera sensor will affect the image quality and resolution of the camera. A larger sensor can capture more detail and produce higher quality images.
- **Resolution:** The resolution of the camera will determine the number of pixels in the image, which affects the level of detail and clarity.
- **Frame rate:** The frame rate refers to the number of frames captured per second, which affects the smoothness of the video footage.
- **Aperture:** The aperture of the camera lens controls the amount of light that enters the camera, which can affect the image quality and depth of field.
- **Focal length:** The focal length of the lens depicts view and magnification of the field image.
- **Image stabilization:** Image stabilization technology can reduce the impact of drone movement on the quality of the footage.
- **Connectivity:** The camera system must be designed to be compatible with the drone's communication and control systems, and may include wireless transmission of data and images.

Ultimately, the specific formula for a drone camera system will depend on the unique requirements and specifications of the drone and its intended use.

Pros: Provides drone visualization and its payload, captured images as forensic evidence for the use of law enforcement investigations.
Cons: Is difficult to use automatic detection in darkness and performs poorly in fog and has a higher chances of false alarming rate.

3) GPS Tracking Systems

Radars are a crucial component of many modern drone systems, providing essential capabilities such as obstacle detection and avoidance, target tracking, and even weather monitoring. Here are some of the ways in which radars are used in drones:

- **Obstacle Detection and Avoidance:** One of the most important uses of radars in drones is to detect and avoid obstacles in the drone's flight path. This is particularly important when drones are used for tasks such as search and rescue or package delivery, where they need to fly autonomously and avoid obstacles without human intervention.
- **Target Tracking:** Radars can also be used to track targets on the ground or in the air, allowing drones to carry out tasks such as surveillance or reconnaissance. By using radars to track targets, drones can operate at longer ranges and in more challenging environments than would be possible with visual sensors alone.
- **Weather Monitoring:** Some drones are facilitated with radars to detect and monitor weather conditions viz. wind speed, direction, temperature and humidity. This information is particularly useful for drones that are used in agriculture or environmental monitoring, where accurate weather data is essential.
- **Mapping:** Radars can also be used to create high-resolution maps of the terrain below a drone. By using a technique called Synthetic Aperture Radar (SAR), the radar on the drone can bounce signals off the ground and use the reflections to build up a detailed 3D map of the area.

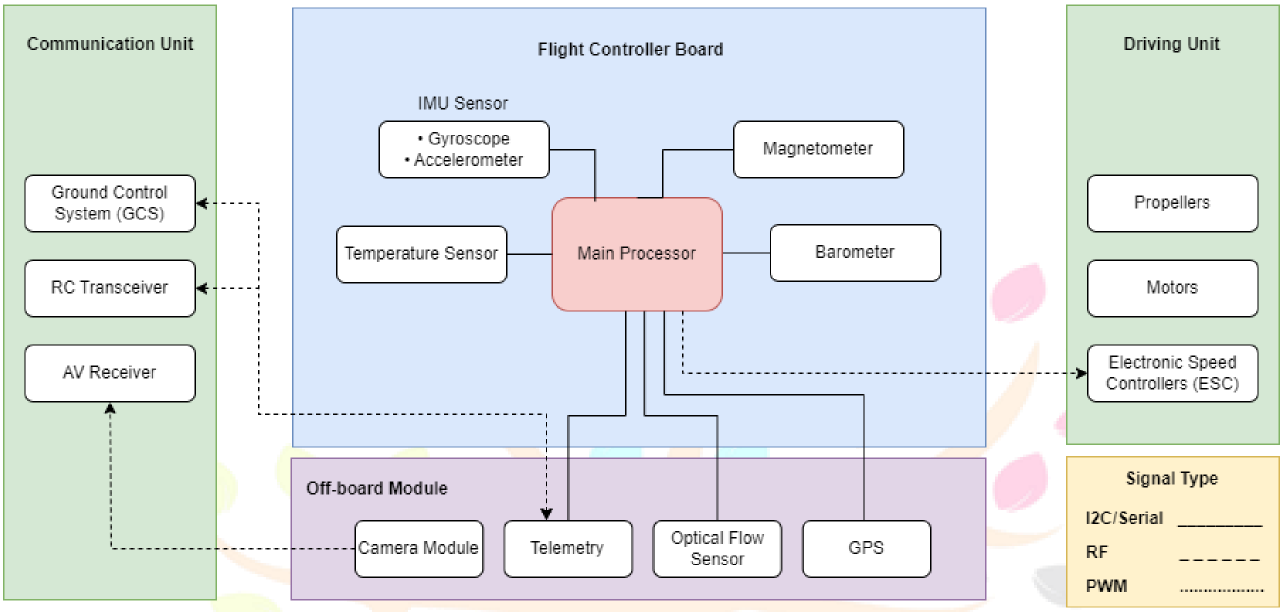

Fig. 3.1 – architecture of GPS tracking system

There are different types of drone GPS tracking systems with various formulas, but here are a few common formulas used:

1)Distance Formula: It's useful in calculating the distance between two points in a 2D coordinate system. For example, if you have the coordinates of the drone's starting location and current location, the Distance Formula can calculate the traveled distance of the drone.

Distance = $\sqrt{((x2 - x1)^2 + (y2 - y1)^2)}$

Where:
x1, y1 = the starting coordinates
x2, y2 = the current coordinates

2)Speed Formula: It's useful in calculating the speed of the drone which is based on the distance traveled and the time taken for that distance travel.

Speed = Distance ÷ Time

Where:
Distance = Drone's traveled distance
Time = Time taken for that traveled distance

3)Bearing Formula: It's useful in calculating the angle between the drone's current location and destination location.

Bearing = atan2 (sin (Δlong) * cos (lat2), cos (lat1) * sin (lat2) – sin (lat1) * cos (lat2) * cos (Δlong))

Where:
lat1, long1 = the starting coordinates
lat2, long2 = the destination coordinates
Δlong = long2 - long1

Note: These formulas may be modified or combined with other formulas depending on the specific drone tracking system.

Overall, the use of radars in drones has revolutionized many aspects of drone technology, enabling them to carry out complex tasks safely and efficiently in a wide range of environments.

Pro: Long distance tracking with precise localization can handle hundreds of targets to track all the drones regardless of autonomous flight and visual conditions viz. day, night and fog simultaneously.
Cons: Drone size matters in range detection which does not recognize birds from drones, It requires transmission license and frequency check to prevent interference.

4) Radio Frequency (RF) Detectors:

Radio frequency (RF) is an essential component in the operation of many drones. Drone Radio Frequency (RF) detectors are devices that are designed to detect the radio signals transmitted by drones. These devices work by scanning the radio spectrum for signals that are commonly used by drones, such as the 2.4 GHz and 5.8 GHz frequencies.

Drones use RF communication to receive control signals from the remote pilot, as well as to transmit video and other data back to the pilot. RF communication operates through the use of radio waves, which are a type of electromagnetic radiation. The radio waves are transmitted by the drone's radio transmitter and received by the radio receiver in the remote controller. The radio waves are then translated into the drone's movements, such as changes in altitude, speed, and direction.

The most common frequency bands used for drone communication are 2.4 GHZ and 5.8 GHZ. The 2.4 GHZ band is useful for basic drone control, while the 5.8 GHZ band is normally used for transmitting video and other data. Different countries have different regulations of Drones RF Communication. The United States FCC (Federal Communication Commission) regulates Drones RF communication by certifying it. Though, there are restrictions on the power output of the RF transmitter used by the drone.

When a drone is detected, the RF detector can alert the operator, providing an early warning system that can help prevent unauthorized or illegal drone use. Some RF detectors are also able to identify the specific type of drone, allowing for targeted responses.

RF detectors can be used for a variety of purposes, such as protecting critical infrastructure, securing public events, and enforcing no-fly zones. However, it is important to note that RF detectors are not foolproof, as drones can use encryption or other techniques to avoid detection. Additionally, it is important to use RF detectors responsibly, as they can also detect legitimate wireless devices, such as Wi-Fi routers and cell phones. As such, RF detectors should only be used by trained professionals in appropriate settings, and should not be used for illegal surveillance or other illicit activities.

There are different types of drone radio frequency detectors, each with its own specific formula. Here are some of the most common formulas used for detecting drone radio frequencies:

- **Signal Strength Formula:**
This formula calculates the strength of the signal emitted by the drone. It's measured in decibels (dB), and it's calculation are as follows:

Signal Strength (dB) = 10 log (p/p0)

Where
P = Drone Signal Power, and P0 = Reference Power Level.

- **Frequency Formula:** It calculates drone signal frequency to measure in Hertz (Hz), and it is calculated as follows:

Frequency (HZ) = Speed of light (M/S) / Wavelength (M)

Where
Approximately Light speed is 3x10^8 m/s
Where the wavelength = Distance between two consecutive peaks or channel of the drone signal.

- **SNR (Signal to Noise Ratio) Formula:** It calculates the ratio between signal power and noise power to determine the quality of the drone signal. It's calculated formula is as follows:

SNR (dB) = 10log (Signal Power / Noise Power)

Where
The power of the drone signal
Where Noise Power is the power of any unwanted signals or noise that exists in the environment.

(Note: The actual implementation of these formulas may differ depending on the specific drone radio frequency)

5) Anti-drone Systems:

Anti-drone systems are designed to detect, track, and neutralize drones that are being flown in unauthorized or unsafe ways. These systems use a variety of technologies and techniques to accomplish their goals. Some common types of anti-drone systems include:

- **Radar systems:** These systems use radar technology to detect drones in the air. They can track the drone's location, speed, and altitude, and provide real-time information to operators.
- **Radio frequency (RF) jamming systems:** These systems use radio waves to disrupt the drone's communication with its operator. By jamming the drone's radio signals, the drone can be prevented from following its intended flight path or carrying out its mission.
- **EO (Electro-optical) and IR (infrared) systems:** It uses cameras and sensors for visually drone detection. So it can track the drone's movements, identify its location, and provide real-time video feeds to operators.
- **Drone capture systems:** These systems are designed to physically capture the drone in the air. They use nets, cages, or other devices to trap the drone and bring it down safely.
- **Laser systems:** uses laser beams to disable or destroy drones in flight. It can target the drone's propulsion system, battery, or other critical components to bring it down.

These sensors will gather RF signals, video images, and acoustic signals, and send them to the central processing unit. Installation purpose of ADS-ZJU is for the experimental evaluation on the rooftop of the ISEE (Information Science and Electronic Engineering) building at Zhejiang University.

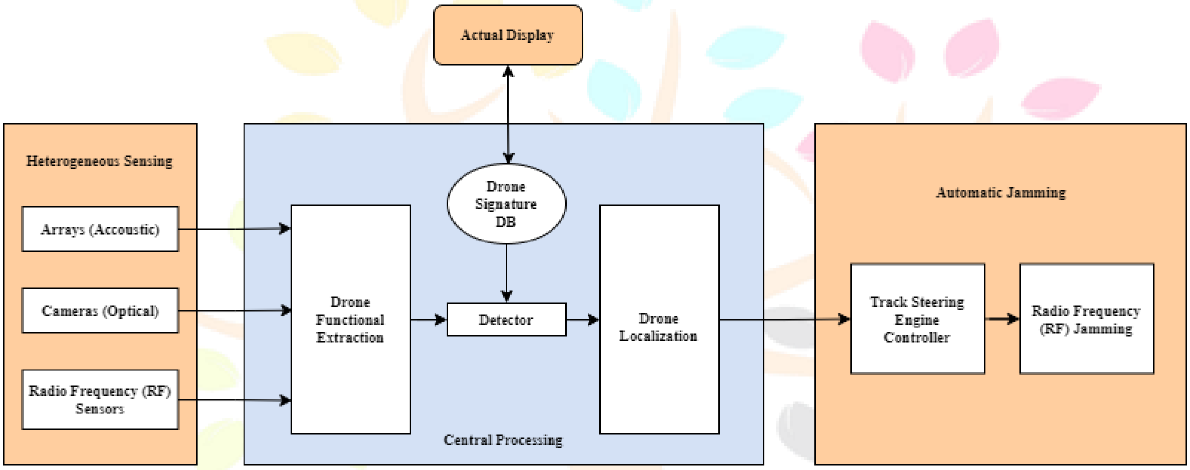

Fig. 5.1 anti-drone system architecture (ADS-ZJU)

Anti-drone systems are typically used in sensitive areas such as airports, military bases, and government buildings, where drones could pose a security risk. However, they can also be used in public spaces, such as stadiums or large events, to prevent drones from interfering with the event or posing a safety risk to spectators.

An anti-drone system is known as ADS-ZJU which groups audio, video and radio frequency with 3 different surveillance technologies. Fig. 1 illustrates ADS-ZJU architecture with four parts
1) Heterogeneous sensing unit,
2) Central processing unit,
3) Automatic jamming unit and
4) Actual display unit.
Let's deep dive in detail for each part and take DJI Phantom 4 as a reference of each part.

Heterogeneous Sensing Unit (Fig. 5.1(a)):

Three different types of sensors are used inside the heterogeneous sensing unit which is depicted in above Fig. 5(a), (b) and (c) to collect data for detecting drones and their positioning.

(a) The Acoustic Sensor is a YG-201 type preamplifier and CHZ-213 type half inch free-field microphone. We construct L-shaped acoustic arrays with 4 uniformly spaced acoustic sensors on each side of it;
(b) The optical camera is built-in with HIKVISION DS-2DF7330IW Network and PTZ type cameras, allowing 360° horizontally rotation and -2~90 vertically rotation with both automatic and manual priorities;
(c) The software radio useful for the USRP-2955 RF sensors, it has 4 different configurable RX channels to receive RF signals between 10MHZ and 6GHZ.

Central Processing Unit (Fig. 5.1(b)):

The CPU (Central Processing Unit) is the main functional part of ADS-ZJU development to conduct drone functional, extraction, detection and localization.

1) **Drone feature extraction:** Drone detection requires the drone features extraction. Using the DJI Phantom 4 we examine the features of the drone using the audio signals, video, and RF signals that were received.

- **Acoustic features:** The incoming acoustic signal's spectrum function is retrieved using a technique called STFT (Short Time Fourier Transform). The STFT (Short Time Fourier Transform) which is a result of the acoustic signals generated for DJI Phantom 4. The strength of the acoustic signals at various frequencies is illustrated in this figure with various colors. DB is the measuring unit for strength levels. It is obvious that the DJI Phantom 4's acoustic signals are chromatic signals with a fundamental frequency of roughly 180 Hz. Although the power of harmonics is varied from one another while their distribution is fairly constant.
- **Image feature:** Drones picture functionality uses HOG (Histograms of Oriented Gradients), one of the most useful functionality descriptors for object detection. The HOG functionality of an image window is useful in describing the features of the drone because it takes up a small size of an image.
- **RF features:** Spectrum Analyzer is useful to test the communication functionality between the DJI Phantom 4 and controller. Research shows that the 2.4 - 2.48GHZ frequency spectrum is divided into 8 communication channels with a bandwidth of 10MHZ when the drone communicates with the controller at channel 2.44 - 2.45GHZ.

2) **Drone detection:** Drone detection uses the linear SVM (Support Vector Machine). Prior to online identification, we will first do offline training to create drone classifiers that can distinguish the drones' vector features from other objects. We collect significant drone audio, visual, and RF signal quantities and extract the corresponding vector feature as other objects in the nearby areas.

3) **Drone localization:** After drone detection, location data will be extracted from the received acoustic signals, video images and RF signals for the drone localization. Music algorithm is one of the most popular DOA techniques that is useful in DOA measurements to estimate L-shape acoustic arrays of the acoustic signals. In relation to the RF sensors, it is possible to fetch RSS & DOA values both from the RF signals.

Automatic Jamming Unit (Fig. 5.1(c)):

Auto jamming devices with ADS-ZJU RF jamming are useful to fly within sensitive areas as a defense mechanism of the drones. Normally the automatic jamming device comprises four elements as indicated in above. 2 steering engines, one of which is capable of 360° degree horizontal rotation and vertical rotation of 180°, a steering engine controller, a planar directional antenna with a 14 dBi antenna and an RF signal generator improves @ 2.4 – 2.5 GHZ frequency included range. The automatic jamming unit will calculate a 3 dimensional angle of the detected drone once it receives the signal of estimated location of the drone with panel antenna.

Actual Display (Fig. 5.1(d)):

LCD (Liquid Crystal Display) real time display device 46 inch screens size to display the drone monitoring results. We can choose from 1 to 4 scenes. Display Screen displays various results such as Acoustic Waves DOA Estimates, the real time incident of the detected drone, the detection of video surveillance results, the autonomous jamming unit that travels towards the detected drone and more.

An anti-drone system can be formulated as follows:

- **Detection:** The system must be able to detect the presence of a drone in the area. This can be done using various sensors such as radar, acoustic sensors, and cameras.
- **Identification:** Once a drone is detected, the system must be able to identify the type of drone and whether it poses a threat. This can be done using machine learning algorithms that can distinguish between different types of drones and their behavior.
- **Tracking:** The system must be capable of tracking real time drone's movements. This can be done using advanced algorithms that can predict the drone's path based on its current speed and direction.
- **Interception:** The system must be able to intercept the drone and prevent it from reaching its intended destination. This can be done using various methods such as jamming the drone's communication or using physical means to disable it.
- **Neutralization:** The system must be able to neutralize the drone without causing harm to people or property in the area. This can be done using non-lethal methods such as net guns or water cannons.

6) Drone Detection Software:

Drone detection software is designed to detect and identify drones in the air using a variety of technologies, such as Radar, RF (radio frequency) detection and Acoustic Sensors. Some common types of drone detection software include:

- **Detection based on Radar:** This software uses radar technology to detect drones in the air. The software can track the drone's location, speed, and altitude, and provide real-time information to operators.
- **RF (Radio Frequency) Detection:** This software detects drones by monitoring their radio frequency emissions. It can detect the drone's communication signals with its operator and distinguish them from other radio frequency signals in the environment.
- **Acoustic Detection:** This software detects drones by analyzing the sounds they produce. It can distinguish between the sounds of drones and other background noises, such as birds or airplanes.
- **Optical Detection:** This software uses cameras and sensors to detect drones visually. It can track the drone's movements, identify its location, and provide real-time video feeds to operators.

- **AI (Artificial Intelligence) based detection:** This software uses machine learning algorithms to analyze sensor data and detect patterns that indicate the presence of a drone. The software can learn and adapt to new drone models and behavior over time.
- **Drone Detection Software**: It can be used in various settings, such as airports, critical infrastructure facilities, and public events, to detect and identify drones that may pose a security risk. The software can also be integrated with other technologies, such as anti-drone systems, to provide a comprehensive solution for drone defense.

LATEST UPDATES

Drones are famous as UAVs (Unmanned Aerial Vehicles) and have seen a drastic increase in its likeness from the last few years. Also started its use for a wide range of applications, including surveillance, delivery, agriculture and entertainment. The latest drone's research and development have focused on improving their capabilities in terms of range, endurance, payload capacity and autonomy.

- **Improved Battery Technology:** One of the biggest challenges with drones has been their limited flight time. However, recent advances in battery technology have led to longer flight times and increased payload capacity. For example, lithium-polymer batteries can now power drones for up to an hour.
- **Sense and Avoid Technology:** Another area of development is sense and avoid technology, which allows drones to detect and avoid obstacles in their flight path. This technology is essential for the safe and autonomous drone operation. Various sensors such as LIDAR, RADAR and cameras are being used to provide situational awareness with the drone.
- **Artificial Intelligence:** AI (Artificial Intelligence) is playing an important role in drone development. Machine learning algorithms are being used to enable drones to recognize objects, detect anomalies, and make decisions based on their observations. This allows drones to perform complex tasks autonomously.
- **Swarm Intelligence:** Swarm intelligence is another area of development in drones, where multiple drones can work together to achieve a common goal. This technology has applications in search and rescue, precision agriculture, and surveillance.
- **Delivery Drones:** The delivery industry has been exploring the use of drones for package delivery. Amazon has already conducted successful drone delivery tests, and many other companies are following suit.
- **Urban Air Mobility:** Urban air mobility is a new area of development that involves the use of drones for personal transportation. Companies like Uber and Airbus are investing heavily in this technology.
- **5G Connectivity:** 5G technology has the potential to revolutionize the way drones are used. It provides faster connectivity, enabling drones to transmit real-time data and receive commands quickly. Overall, the latest research and development in drones are focused on improving their capabilities, making them safer, and enabling them to perform complex tasks autonomously.

CONCLUSION & REVIEW

In conclusion, agricultural drone technology has the potential to revolutionize the way we approach agriculture. These drones can provide farmers with valuable insights into their crops and land, enabling them to make informed decisions about irrigation, fertilization, and pest management. They can also help farmers save time and resources by automating certain tasks, such as mapping and surveying.

However, there are some challenges associated with the use of agricultural drones. For one, the technology is still relatively new, and there may be issues with reliability and accuracy. Additionally, there are concerns about privacy and data security, as well as regulations surrounding drone usage. Despite these challenges, the potential benefits of agricultural drone technology are significant, and it is likely that we will continue to see advancements in this field in the coming years. As drones become more sophisticated and reliable, they may become an increasingly valuable tool for farmers looking to maximize their yields and minimize their environmental impact.

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