Remote detection, recognition and tracking of objects in drones aircraft

Ivanova Eleonora, Stefanov Ivan
1Faculty of Computer Systems and Technologies, Technical University - Sofia, Blvd. Kliment Ohridski 8, 1000 Sofia, Bulgaria
E-mail: el_ivanova@tu-sofia.bg, ivan.ts.stefanov@tu-sofia.bg

Abstract: *A review and analysis of methods for the detection and recognition of unmanned aerial vehicles (UAVs) has been carried out. UAV detection channels were considered - acoustic, optical, radar, infrared, radio reconnaissance channel. The advantages and disadvantages of the channels used are compared and evaluated. In the case of small UAVs, there are a number of significant difficulties and limitations. One of the directions in UAV detection is acoustic observations. The noise created by the UAV's power plant and propeller is an important unmasking feature. The creation and improvement of methods for the detection, direction-finding and recognition of small UAVs by receiving and processing their sound signals is an urgent task. In the implementation of this method of detection of UAVs are used frequency spectra, spectrograms, normalized autocorrelation functions and phase portraits of acoustic signals. Information features of the UAV sound image can be estimates of spectral coefficients determined from a discrete implementation containing a given number of samples, as well as parameters of autoregressive models.*

KEYWORDS: *MULTISENSOR SYSTEM, DETECTION AND CLASSIFICATION, UNMANNED AERIAL VEHICLES, ARTIFICIAL INTELLIGENCE, HUMAN FACTOR, COMMUNICATION AND INFORMATION SYSTEM, NETWORK-CENTRIC ENVIRONMENT*

1. Introduction

One of the most important tasks in ensuring security against threats arising from the use of unmanned aerial vehicles (UAVs) is their detection and determination of their movement parameters.
The following requirements apply to UAV detection equipment:

- high target detection efficiency; ease of use; profitability (low cost); safety for people and wildlife; absence of obstacles in the operation of other technical systems.

2. Methods for detection and determination of UAV motion parameters

Currently, the most common methods for detecting and determining UAV movement parameters are:

- radio technical control (RTK); radar control; optical control; acoustic control.

In radiotechnical monitoring, two methods of obtaining information are used: search and observation. **[1]**
The search includes detection of radio signals from radio emission sources (ERS), their technical analysis, recognition of radio signals of ERs, recognition of ERs themselves and processing of spatial parameters of radio signals (bearing of ERs) to determine the coordinates of emitters.
The surveillance includes the implementation of radio interception operations of RES messages, tracking of the trajectory of RES, technical analysis of radio signals and recognition of RES signals.
The main tasks of radio technical control are:

- search and detection of UAV radio signals during panoramic viewing in the required frequency range or when tracking a fixed set of frequencies; determination of parameters and type of modulation of detected signals; demodulation of certain types of signals; determination of the type and structure of binary sequences (protocols), types of synchronization, primary and noise-resistant coding;

decoding and extracting messages; logging signals and messages, archiving data; direction finding of radioactive sources and determining their location during search; tracking the trajectory of the UAV during surveillance.
To solve these problems, it is necessary to use automated radio engineering control systems that provide:

- setting alerts; automatic scan (review) in a set range with display of scan results; determination in automatic mode and in dialogue mode with the operator of the modulation parameters of the analyzed signals; demodulation of certain classes of signals; Recording of signals on computer media; maintaining a database of processed signals; signal classification and exposure detection; direction finding and location determination of the UAV. **[2]**

Currently, unmanned aerial vehicles (UAVs) are widely used in various fields of human activity. For example, in agriculture, UAVs with GPS navigation are used to pollinate plants in fields. At the same time, significant savings in chemicals and more thorough crop treatment are achieved compared to manned aircraft. UAVs are used to deliver medicine and humanitarian aid to hard-to-reach areas and can be used to inspect power lines and pipelines. Drones, another name for UAVs, can also be used by the state emergency service for surveillance and forecasting, as well as for the control of dangerous sites.

3. Main types of UAVs

Based on the variety of designs, there are four main types of UAVs. Fig. 1.

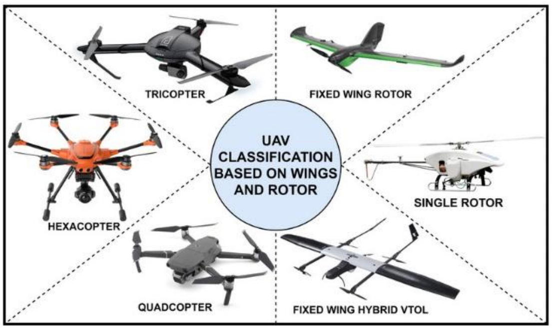

Fig. 1. *Classification of UAV based on wings and rotors.*

Multicopter drones are a flying platform with brushless motors and propellers. They have the ability to take off vertically or hover over an object and are the cheapest and most accessible version of UAVs. **[3]** Fixed-wing UAVs fulfill the structure of an aircraft and are ideal for long-range operations. Single-Rotor Drones – Unmanned helicopters are much more efficient than the multi-rotor versions. They have longer flight times and can even be powered by internal combustion engines. Hybrid drones are also known. As drones become more common, the issue of detecting UAVs in the air becomes more relevant. The following methods and means are used for this: radar, optical and acoustic. UAV optical detection is highly dependent on environmental factors. Increasing the detection range is achieved by narrowing the field of view, reducing the field of view and increasing the search time. Therefore, visual sensors are inefficient search devices. The use of acoustic channels for UAV detection is becoming more and more relevant. Acoustic sensors allow ground assets to search for and detect UAVs in passive mode, thereby reducing the likelihood of the enemy identifying their own positions. Therefore, modifying existing acoustic search systems or creating new systems can provide a reliable method of UAV detection. Drones can also be detected by receiving and analyzing radio signals: communication and control links, radar altimeters, active jammers and radar stations. However, this method can only determine the direction to the UAV, and the accuracy of the determination increases as the observation time increases. Some low-frequency communication links can be detected over considerable distances. Emissions from airborne radar stations (radar) and active jamming of UAVs can be detected at even greater distances. This method requires minimal equipment and allows you to quickly determine the direction of the target for further issuing target designations to optical or infrared surveillance equipment. **[4, 5]** Searching for UAVs using active radar stations is quite productive, since they have a relatively large pulse search volume and a significant detection range. A significant drawback of the radar method is that most UAVs are made of composite materials that reflect electromagnetic waves rather poorly. Radio waves penetrate the surface of the device and are only partially reflected by it. Another problem is that due to the small size of UAVs, bandwidth limitations and, importantly, high cost, surveillance radars cannot be used often, especially when a network of radars needs to be deployed to ensure full coverage of the controlled area. Continuous wave (CW) and frequency modulated continuous wave (FMCW) radars currently represent the most attractive and cost-effective solution to this problem. An FMCW signal consists of a linearly modulated continuous wave transmitted in the desired direction. These types of signals differ from a CW signal where the operating frequency does not change during transmission. In most cases, target detection aims to detect the presence of objects that are not constant in the observed scenario, that is, objects that can dynamically appear or disappear. The moving target indicator is a mode of operation of the radar that allows the system to distinguish the target both among noise and among stationary objects in the observation area. This property is based on the Doppler effect, since stationary targets do not cause any Doppler frequency shift in the observed signals. Thus, the main method for detecting UAVs at significant distances is the radar method and the corresponding radars, characterized by a significant energy potential.

In world practice, there are two approaches to detecting objects using infrared (IR) images. The first approach is related to identifying an object by its own radiation using thermal imaging cameras. The spectrum of the object's own radiation is in the range of 7-14 microns. Modern thermal imaging cameras have a light temperature sensitivity of about 0.05 K. In the future, such systems should be equipped with a zoom lens up to 10-20 times. The second approach involves the use of active infrared laser illumination, for example, an infrared laser of 903 nm or 1560 nm for object detection and identification, topography of the area with subsequent identification of moving UAVs against the background of moving wildlife objects. In order to be able to detect UAVs at a distance of up to 2 km, the authors suggest using 1560 nm with a pulse duration of 1 ns, a repetition rate of 1 MHz and a pulse power of 700 kW. The divergence of the laser beam is of the order of 0.5 degrees In this case, the system is equipped with a matrix photodetector (150 x 20 pixels) and an optical system so that the angular field of view of the matrix photodetector corresponds to the angular field of the laser beam. In other words, the system works by recording the reflected signal from the UAV in a given angular space from a matrix photodetector unit (PDU). The scanning system is equipped with a high-speed galvanometric mirror (f = 1 kHz) for sequential scanning of the laser illumination field. Such systems also perform the function of a laser range finder - LIDAR. **[6, 7]** Fig. 2.

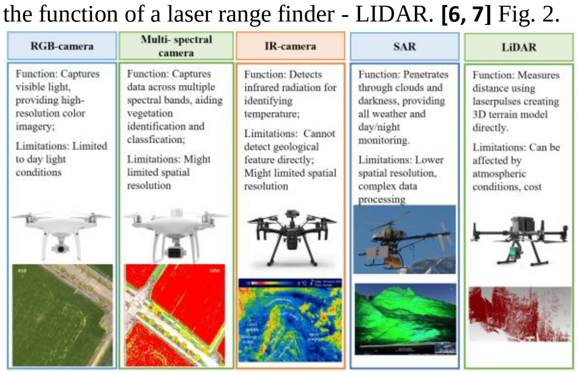

Fig. 2. *Functions and limitations of on-board sensors.*

4. Optical spectral methods

The ability to use optical spectral methods to solve problems with the detection and recognition of unmanned aerial vehicles against the background of wildlife objects largely depends on the power of the radiation sources, which decreases with increasing distance to the object and the sensitivity of the recording equipment . Estimating the potential maximum detection distances of UAVs using optical methods requires further basic science research. The goal of such research should be to develop the scientific foundations for remote detection, identification, tracking and determination of UAV parameters and UAV membership in different groups using optical localization methods and optical spectroscopy, as well as automatic optical recognition in different environments of the background of moving live objects. Research should encompass existing and promising spectral optical methods aimed, among other things, at identifying new informative detection features. **[8, 9]** For their implementation, an experimental bench is created, which enables the implementation of the research objectives.

5. Conclusion

The analysis of the modern state of methods and technical means, optical location and optical spectroscopy showed the prospects for use in problems with the detection and identification of moving objects. At the same time, a complete effective system for spectral optical control of UAVs has not yet been created, as many unsolved problems, such as the speed of neural networks and the need for their constant training; physical limitations of the range of different types of optical methods; the complexity of the task of remote differentiation of objects of different nature. To solve them, it is necessary to combine methods of optical location and spectral analysis, methods of statistical theory, graphics, machine learning, neural networks and automatic control methods, which is an interdisciplinary fundamental scientific problem.

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