Chapter 17
Examination of Different Systems Used for UAV Detection and Tracking

Alpaslan Durmuş and Erol Duymaz

17.1 Introduction

UAV systems are spreading rapidly nowadays. The main reasons for the rapid growth of the UAV industry are: it can transfer low-cost video and images and be used for logistics purposes in different areas. At the same time, UAV systems can be designed in different body structures. This situation increases the demand for UAV systems. It is stated that more than 10,000 UAVs will be operational for commercial use in 5 years (Chan et al. 2018). UAV systems offer more cost-effective solutions than other aircraft (Erdelj et al. 2017). The use of UAV systems is not limited to commercial or hobby use.

Together with technological developments and their integration into UAV systems, these systems are used in many different fields for the benefit of humanity. Some of these areas are:

- Reconnaissance and surveillance by security forces.
- Gathering information about the victims by search and rescue teams by search and rescue teams such as AFAD (Disaster and Emergency Department) in case of accident or natural disaster.
- Transportation of commercial materials for logistics purposes.
- Receiving video or images in the field of advertising or publishing.

They can be listed as the use of different camera technologies (multispectral) to be used in integration with UAV systems in the field of agriculture, to monitor product developments, or to carry out agricultural activities such as product spraying (Yaacoub et al. 2020).

A. Durmuş (✉) E. Duymaz
Ostim Technical University, Ankara, Türkiye
e-mail: alpaslan.durmus@ostimteknik.edu.tr

T. H. Karakoc et al. (eds.), *Advances in Electric Aviation*, Sustainable Aviation,
https://doi.org/10.1007/978-3-031-32639-4_17

Today, especially for hobby purposes, UAV systems with a takeoff weight of less than 500 g are seen more intensely around us. UAV systems with a takeoff weight of less than 500 g are excluded from classification according to SHGM (General Directorate of Civil Aviation) regulations. These UAV systems deployed under 500 g have the potential to pose a security threat (Öz and Sert 2019). These systems can easily be used for illegal purposes such as terrorist attacks, illegal surveillance and reconnaissance, smuggling, and electronic surveillance, and also pose a potential collision risk in aircraft flying legally (Sommer et al. 2017).

According to the United States (US) Federal Aviation Administration (FAA), more than 3 million UAV systems are registered in the United States. The number of UAVs is expected to reach 7 million by 2020. In addition, it is estimated that the technological and economic growth of e-commerce will bring about the more widespread use of UAV systems and the change of regulations. It is seen that the widespread use of unmanned aerial vehicles will increase security threats. In this context, there are UAV identification, tracking and blocking systems with different features to prevent security threats that may arise from UAV systems.

In this study, different techniques used for identification, classification, monitoring, and blocking of UAV systems were examined.

17.2 Investigation of UAV Detection and Monitoring Systems

Different technologies and systems are used to detect UAV systems. In this context, there are four most used systems. These are: radar, acoustic detection, radio frequency system, and electro-optical detection systems. These systems are explained below according to their basic features.

17.2.1 Radar

Radar systems are ineffective against small UAVs as they are developed to detect large air platforms moving at high speeds. Since UAV systems fly at similar speeds and altitudes to birds, they cannot detect the difference between two objects (Coluccia et al. 2020).

17.2.2 Acoustic Detection

Acoustic sensors work by identifying the distinctive noise made by the UAV's engines. They work by utilizing a database of acoustic signatures of commonly used UAV engines. The most important advantage of acoustic sensing is its low cost even when used as a network of sensing devices placed around the protected area (Yang et al. 2019). However, acoustic detection cannot detect gliders or fixed-wing UAVs. Advanced operators can change a UAV's sound signature by purchasing different propellers or making other modifications. The effective working range is 500 m. It is unlikely to provide reliable detection at greater distances and is ineffective in urban areas with a lot of ambient noise.

Advantages:

- It has a lower cost compared to RF-based systems.
- It can be produced in smaller sizes in terms of volume.
- It can operate with high performance in areas with high magnetic frequency pollution.
- Due to its low cost, it can be used in integration with other systems.
- It is very suitable for machine learning algorithms in obtaining information such as drone type, brand, flight characteristics.

Disadvantages:

- It can work effectively at a distance of about 500 m. Since the cost is low, it is possible to create a network structure with more than one and increase the distance.
- Its performance decreases in areas with sound and noise pollution.
- It cannot make environmental perception.

17.2.3 Radio Frequency (RF) Emission Detection

To control the UAV systems, communication is provided between the transmitter and the receiver on the UAV using the RF band. Using antennas or a network of synchronized ground stations, such RF transmissions can be detected and located. For the system to be economical and to offer fast detection, the system must have data recorded in the database about the propagation frequencies and bandwidths arranged for commercial UAVs (Guvenc et al. 2018).

The ILTER system developed in Turkey works on an RF basis. It captures and automatically blocks communication signals between ground control stations and controls of rotary or fixed-wing mini/micro-UAVs with its RF sensors. ILTER RF Drone Detection and Interception System, which is widely used in Turkey, has a fully automatic detection, jamming, and deception feature against drones/UAVs. The features of the ILTER system developed in this context are given below.

- Detects rotary-wing and fixed-wing low-altitude UAVs.
- Detects the wireless communication between the drone and its remote control.
- Detects frequency bands in the UHF, S and C range.

Advantages:

- It has a wider coverage area compared to acoustic systems in terms of operating range.

- It can detect 360 degrees peripherally.

  Disadvantages:

- It has a higher cost compared to acoustic systems.
- Working performance decreases in areas with high magnetic pollution such as airports.
- It has a jamming feature, but today's drone systems can understand the jamming and put itself in autonomous mode and complete the flight route.
- It is difficult to obtain information such as drone type, brand, flight characteristics.

17.2.4 *Electro-Optical (EO) Detection*

Electro optical sensors in the form of optical and thermal cameras are very effective in detecting UAVs. However, optical cameras have problems in distinguishing small objects from UAVs. With the use of computer algorithms, a bird can be distinguished from a UAV.

17.3 Conclusion

Below is a comparison of different systems used for UAV detection. These systems have different advantages and disadvantages. Table 17.1 shows the advantages and disadvantages of these systems. The use of different techniques under appropriate conditions will give the most appropriate result.

Table 17.1 Comparison of advantages/disadvantages of different drone detection and tracking techniques (Guvenc et al. 2018)

Detection technique	Advantages	Disadvantages
Ambient RF signals	Low-cost RF sensors (e.g., SDRs), works in NLOS, long detection range. May allow deauthentication attacks for taking control of drone by mimicking a remote controller or spoofing GPS signal	Need prior training to identify/classify different drones. Fails for fully/partially autonomous drone flights due to no/limited signal radiation from a drone/controller
Radar	Low-cost FMCW radars, does not get affected by fog/clouds/dust as opposed to vision-based techniques, can work in NLOS (more sophisticated). Higher (mmWave) frequencies allow capturing micro-Doppler/range accurately at the cost of higher path loss. Does not require active transmission from the drone	Small RCS of drone makes identification/classification difficult. Further research needed for accurate drone detection/classification and machine learning techniques, considering different radar/drone geometries and different drone types which all affect micro-Doppler signatures. Higher path loss at mmWave bands limits drone detection range

(continued)

Table 17.1 (continued)

Detection technique	Advantages	Disadvantages
Acoustic signals	Low cost for simple microphones (cost depends on the quality of microphones). Can work in NLOS as long as the drone is audible	Need to develop database of acoustic signature for different drones. Knowledge of current wind conditions and background noise is needed. May operate poorly under high ambient noise such as in urban environments
Computer vision	Low cost for basic optical sensors. Pervasive availability of cameras even at most commercial drones that can be used as sensors	Higher cost for thermal, laser-based, and wide FOV cameras. Requires LOS. Level of visibility impacted by fog, clouds, and dust
Sensor fusion	Can combine advantages of multiple different techniques for wider application scenario, high detection accuracy, and long-distance operation	Higher cost and processing complexity. Need effective sensor fusion algorithms

References

K.W. Chan, U. Nirmal, W.G. Cheaw, *Progress on Drone Technology and Their Applications: A Comprehensive Review*, in AIP Conference Proceedings, vol. 2030, no. 1 (AIP Publishing, 2018), p. 020308

A. Coluccia, G. Parisi, A. Fascista, Detection and classification of multirotor drones in radar sensor networks: A review. Sensors **20**(15), 4172 (2020)

M. Erdelj, E. Natalizio, K.R. Chowdhury, I.F. Akyildiz, Help from the sky: Leveraging UAVs for disaster management. IEEE Pervasive Comput. **16**(1), 24–32 (2017)

I. Guvenc, F. Koohifar, S. Singh, M.L. Sichitiu, D. Matolak, Detection, tracking, and interdiction for amateur drones. IEEE Commun. Mag. **56**(4), 75–81 (2018)

T. Öz, S. Sert, The present role of anti-drone technologies in modern warfare and projected developments. Güvenlik Stratejileri Dergisi **15**(32), 691–711 (2019)

L. Sommer, A. Schumann, T. Müller, T. Schuchert, J. Beyerer, *Flying Object Detection for Automatic UAV Recognition*, in 2017 14th IEEE International Conference on Advanced Video and Signal Based Surveillance (AVSS) (IEEE, 2017, August), pp. 1–6

J.P. Yaacoub, H. Noura, O. Salman, A. Chehab, Security analysis of drones systems: Attacks, limitations, and recommendations. IoT **11**, 100218 (2020)

B. Yang, E.T. Matson, A.H. Smith, J.E. Dietz, J.C. Gallagher, *UAV Detection System with Multiple Acoustic Nodes Using Machine Learning Models*, in 2019 Third IEEE International Conference on Robotic Computing (IRC) (IEEE, 2019, February), pp. 493–498