Drone detection: Autoencoder to overcome the weaknesses of RF approaches

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Abstract

In the current context, where drones are becoming increasingly accessible, it is essential to be able to detect these drones as quickly and as far away as possible in order to secure no-fly zones. In the current context, where drones are becoming increasingly accessible, it is essential to be able to detect these drones as quickly and as far away as possible in order to secure no-fly zones. The study of radio frequency signals is seen as an effective means of detecting these drones, and detection models that use this data are among the most effective. Here we present a preliminary study aimed at improving the detection of drone signals while reducing its sensitivity to interference.

1. Introduction

The integration of UAVs (Unmanned Aerial Vehicles), commonly known as drones, marks a structural revolution in the organization of our contemporary and future urban spaces. Initially limited to military applications (surveillance drones, tactical drones, etc.) or recreational uses (children's toys, racing drones, etc.), they are now establishing themselves in many feilds. In fact, advances in drone technology are opening up exciting possibilities for our societies. However, today they are often used for illegal purposes and fly over restricted areas. Among the illegal uses [1, 2] of these drones, we can mention their use for espionage, the transport of illegal objects, or even explosive drones. Due to these illegal uses, it is essential to be able to detect these drones in order to neutralize them.

In the case of detection, the literature describes detection tools based on different technologies. Detection can be based on sound analysis [3], video analysis [4], radar analysis [5], or radio frequency analysis [6]. Each of these technologies offers benefits and disadvantages for drone detection and are presented in Table 1. Among these technologies, the study of radio frequency signals offers an ideal compromise between accuracy, distance, no line of sight, and responsiveness.

Technologie	Benefits	Disadvantages
Video	-Provides indisputable visual evidence	-Range limited by weather conditions (fog, rain, obstacle)
	-Allows you to see if the drone is carrying a payload	-Requires a direct line of sight (LOS)
	-Thermal analysis possible at night	-Highly demanding in terms of computing power (AI)
Audio	-Capable of detecting "around the corner" (out of sight)	-Very short range
	-Passive and inexpensive technology	-Highly sensitive to ambient noise
	-Works in total darkness	-Easily fooled by quiet engines
Radar	-Very long range	-high cost
	-Works day, night, and in bad weather	-Active technology (emits waves)
	-Tracks the trajectory in real time	-Difficulty distinguishing a drone from a large bird (false positives)
Radio Frequencies	-Detects the drone before takeoff	-Ineffective against autonomous drones (GPS flight without radio link)
	-Can identify the model and serial number	-Sensitive to interference (Wi-Fi, relay antennas)
	-Passive technology	

Table 1: Benefits and disadvantage of drones detection technologies

In this paper, we will demonstrate the value of incorporating an autoencoder into the detection model in order to improve its effectiveness.

2. Detection and autoencoder

2.1. Experimentation

For this study, we used the drone detection models presented in [7]. We trained this model to detect the radio frequency signals of a DJI MAVIC 2 zoom drone. We built an autoencoder that learned to denoise the signals from these drones using a simple architecture of 8 convolution layers for encoding and 8 deconvolution layers for decoding. This network takes a $512 \times 512 \times 1$ image as input and reconstructs a $512 \times 512 \times 1$ image as output. For recording input signals, we used an SDR card assembled and designed by InoDesign Group based on an ARDV card. This card allows us to simultaneously record four RX inputs. The test bench used to record the data used to train our autoencoder is shown in the Figure 1.

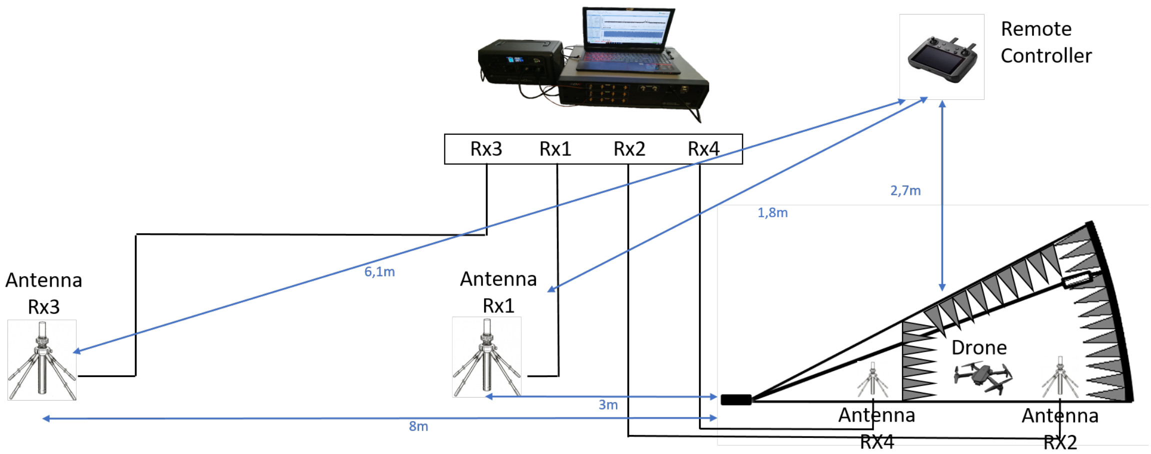

Figure 1: Test Bench

For this experimentation, we configure our SDR card to measure a 100 MHz band centered on the 2.45 GHz frequency. The measurements used as a reference for training our autoencoder are the data measured by the RX4 antenna. With this configuration, we simultaneously have different power levels for reception corresponding to drone signals. As the measurements were taken in our laboratory, the communication traffic present on this band is present but attenuated on the reference antenna. Conversely, for the RX4 reference antenna, the signals emitted by the drones are not attenuated.

2.2. Results

In order to compare the detection results with and without the use of the autoencoder at the detector input, we measured the signals from the drone located at different distances from the equipment on one input of our SDR card. The Figure 2 shows the distance between the RX1 antenna and the drone.

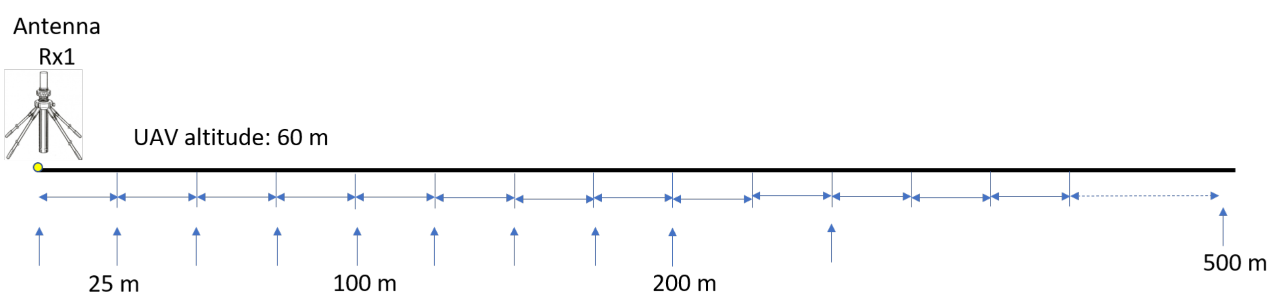

Figure 2: Schematic diagram showing the measurement configurations.

For this experiment, the drone flies above the radio control at a height of 60 meters and we make 10 recordings per position. Based on these measurements, we calculated the average detection probability for the detection model with and without the autoencoder as input to the model. The results are shown in the Figure 3. Even though the autoencoder loses slightly in detection quality at short distances, it greatly improves detection quality at longer distances.

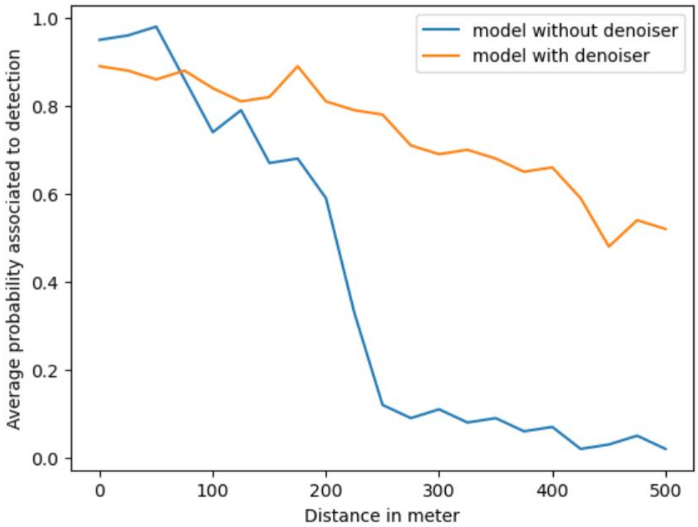

Figure 3: Evolution of detection probability as a function of distance

3. Conclusion

The presence of the autoencoder improves the distance at which the drone can be detected. Adding an autoencoder at the detector input compensates for two weaknesses of radio frequency technology. The first point is that it artificially improves the strength of the drone signal by making it stand out more clearly from the measurement noise. The second point is that it simultaneously reduces the presence of other signals present on the monitored frequency band, which reduces the sensitivity of these detectors to interference.

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References

[1] Ghulam E Mustafa Abro, Saiful Azrin BM Zulkifli, Rana Javed Masood, Vijanth Sagayan Asirvadam, and Anis Laouiti. Comprehensive review of uav detection, security, and communication advancements to prevent threats. *Drones*, 6(10):284, 2022.

[2] Alexander Solodov, Adam Williams, Sara Al Hanaei, and Braden Goddard. Analyzing the threat of unmanned aerial vehicles (uav) to nuclear facilities. *Security Journal*, 31(1):305–324, 2018.

[3] Cătălin Dumitrescu, Marius Minea, Ilona Mădălina Costea, Ionut Cosmin Chiva, and Augustin Semenescu. Development of an acoustic system for uav detection. *Sensors*, 20(17):4870, 2020.

[4] Jie Zhao, Jingshu Zhang, Dongdong Li, and Dong Wang. Vision-based anti-uav detection and tracking. *IEEE Transactions on Intelligent Transportation Systems*, 23(12):25323–25334, 2022.

[5] Jens Klare, Oliver Biallawons, and Delphine Cerutti-Maori. Uav detection with mimo radar. In *2017 18th International Radar Symposium (IRS)*, pages 1–8. IEEE, 2017.

[6] Yongguang Mo, Jianjun Huang, and Gongbin Qian. Deep learning approach to uav detection and classification by using compressively sensed rf signal. *Sensors*, 22(8):3072, 2022.

[7] Driss Aouladhadj, Ettien Kpre, Virginie Deniau, Aymane Kharchouf, Christophe Gransart, and Christophe Gaquière. Drone detection and tracking using rf identification signals. *Sensors*, 23(17):7650, 2023.