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Analysis of Drone Signals Based on Change Point Detection Algorithm

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***Abstract*—The work presents an algorithm characterized by high precision and efficiency in identifying signals related to data transmission between the controller and the drone. Using an efficient change point detection algorithm and parallel analysis capabilities, this method facilitates rapid signal analysis. These features make the proposed algorithm a solid basis for developing an effective anti-drone defense system.**

I. Background

Over the past decade, there has been a rapid expansion of Unmanned Aerial Systems (UASs) across military, commercial, and civilian sectors. However, these developments also pose significant challenges in securing critical infrastructure, including electricity, telecommunications and transport areas. In particular, significant UAS airport disruptions have been observed in recent years, the most serious of which are listed in [1].

Recently, numerous methods have been proposed to detect and classify UAV-related signals to protect critical infrastructure. The solution proposed in [2] introduces a neural network-based approach for signal classification. This approach involves the following steps: 1) creating a signal database; 2) manually labeling and annotating the database, which is rather time-consuming; and 3) employing a neural network to recognize the signals. Alternatively, one can use a general model trained by the DeepSig company, which is continuously updated. This model can distinguish between various signals, like: LTE, Wi-Fi, Bluetooth. The publication [3] describes the implementation of [2] on the efficient HPE Edgeline EL8000 server, which includes model training and signal classification.

An alternative approach to detecting signals related to uplink and downlink data transmission is based on cyclostationarity analysis [4], [5], [6]. It is also used in the analysis of Frequency-Hopping Spread Spectrum (FHSS) signals [7]. In [8] a spectrum sensing method is proposed, which is based on the eigenvalues of the covariance matrix of signals received at the secondary users.

II. The proposed method

In this paper we propose to analyze uplink and downlink data transmission between controller and drone using change point detection (CPD) algorithms, which are typically used to analyze time-series to detect transitions between states of signals [9], [7]. In our approach, CPD is applied independently in separate channels to accurately capture the appearance of very low power signals.

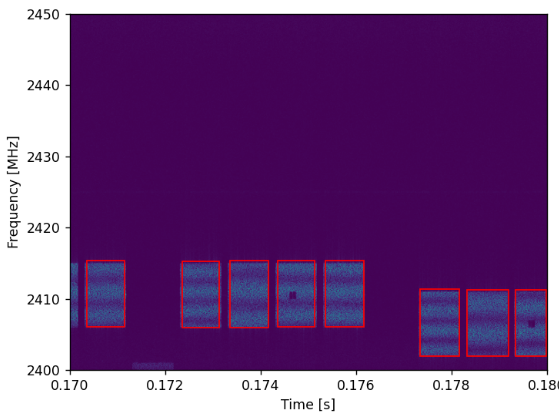

Fig. 1. Spectrogram of the AUTEL Robotics Evo Nano drone signal. Detected signal parts are marked in red.

For clarity, below are the next steps of the proposed drone signal detection algorithm:

1) The short-time Fourier transform (STFT, [10]) is calculated for each set of samples of the measured signal (512 samples in our tests).
2) The vectors obtained as a result of the STFT algorithm create subsequent columns of the spectrogram.
3) The spectrogram is divided into 16 frequency bands.
4) The spectrogram rows in each channel are summed.
5) The change in signal level as a function of time is detected.
6) Next, we use CPD to determine the transmission bandwidth in individual channels.
7) Detected signals are used to predict carrier frequency in the next FHSS hops. For this purpose, we use pattern matching algorithms [11].

In order to test the algorithm, we created a database of signals related to eight drones:

1) AUTEL Robotics Evo Nano
2) AUTEL Evo light +
3) DJI Mini 3 Pro
4) DJI FPV
5) DJI Inspire 2
6) DJI Matrice 300
7) Parrot ANAFI
8) Pixhawk (open standards for drone hardware).

Signals were measured in a real environment with rel-

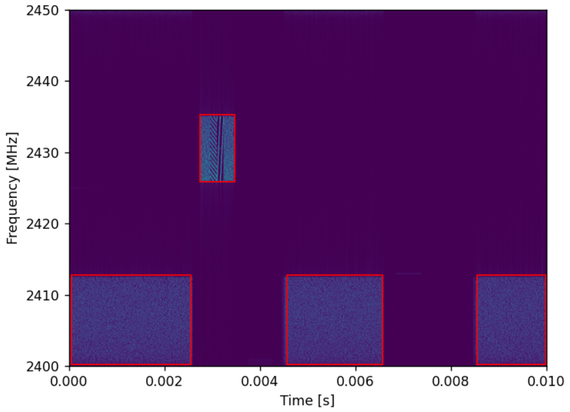

Fig. 2. Spectrogram of the DJI FPV drone signal. Detected signal parts are marked in red.

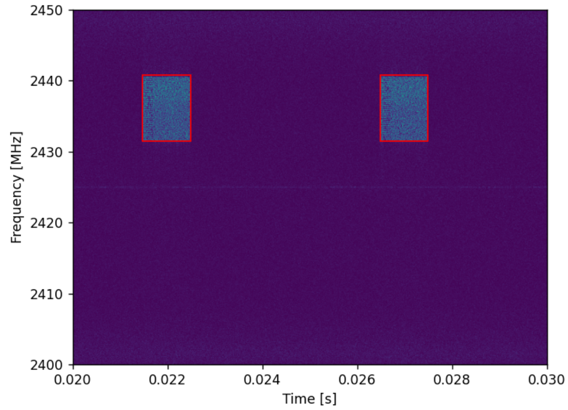

Fig. 4. Spectrogram of the Pixhawk drone signal. Detected signal parts are marked in red.

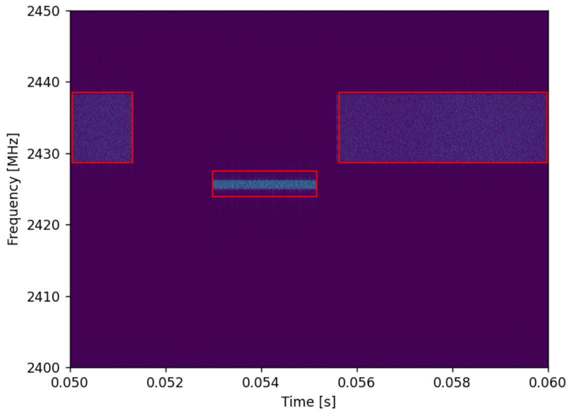

Fig. 3. Spectrogram of the DJI Inspire 2 drone signal. Detected signal parts are marked in red.

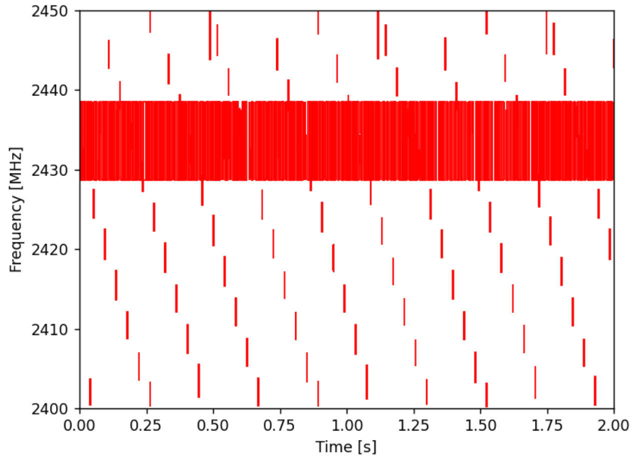

Fig. 5. Spectrogram of the DJI Inspire 2 drone signal. Detected signal parts are marked in red.

atively small interference from external networks. Subsequently, we applied the proposed algorithm to detect signal bursts. In Figures 1-4, one can observe the spectrograms featuring information packets related to both video transmission and signals from the controller. Fragments of the mentioned signals detected by the algorithm are highlighted in red. Figures 5-6 display the detected bursts over an extended time window (2 sec.), showcasing both the video transmission and the Frequency-Hopping Spread Spectrum (FHSS) sequence associated with drone control.

III. Conclusions

It can be noted that the proposed algorithm is characterized by high accuracy in detecting signals related to data transmission between the controller and the drone. At the same time, the method allows for quick analysis of signals thanks to the use of an efficient changing point algorithm and the possibility of parallelizing the analysis. Thanks to these features, the proposed algorithm can serve as the basis for building an effective anti-drone defense system.

Acknowledgment

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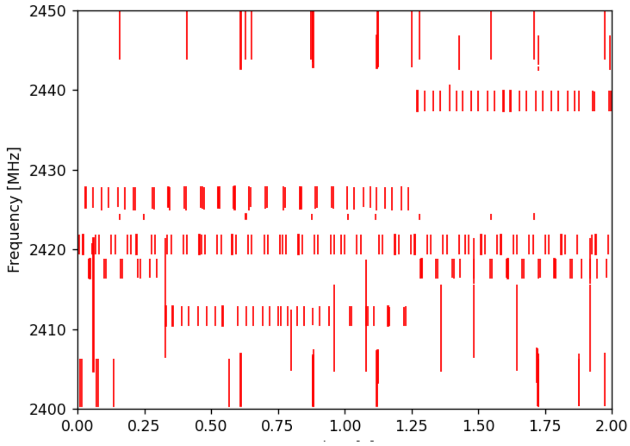

Fig. 6. Spectrogram of the DJI Mini 3 Prom drone signal. Detected signal parts are marked in red.

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