Convolutional Neural Network-Based UAV Classification Using RF Fingerprints

Md Habibur Rahman, Mohammad Abrar Shakil Sejan, Jung-In Baik, Md Abdul Aziz, Rana Tabassum, and Hyoung-Kyu Song*
habibur@sju.ac.kr, sejan@sejong.ac.kr, junginb@sejong.ac.kr, aziz@sju.ac.kr, tanvi@sju.ac.kr, and *songhk@sejong.ac.kr

Department of Information and Communication Engineering and Convergence Engineering for Intelligent Drone, *Sejong University, Seoul 05006, South Korea.

Abstract

Unmanned aerial vehicle (UAV) detection issues can be successfully resolved by machine learning (ML) algorithms effectively. This research presents a developing ML approach called convolutional neural network (CNN) models for the accurate categorization of Micro UAVs, leveraging current breakthroughs in ML technology. To improve computing efficiency over RGB channels, the classification process entails extracting radio frequency (RF) data from several drones and expressing them using grayscale values. We use the DroneRC dataset for this simulation study. Raw RF data is preprocessed using the Short-Time Fourier Transform and the power spectral density technique to extract the most pertinent properties before the ML models are trained. The outcomes of the simulations show that the suggested machine learning models attain a high degree of classification accuracy while minimizing errors during prediction.

Ⅰ. Introduction

In recent times, unmanned aerial vehicles (UAVs), also known as drones, have attracted a lot of attention. UAVs can be flown from kilometers away without a pilot present by using a remote controller. UAVs are used in agriculture to monitor crops and spray fertilizers and pesticides [1]. UAVs are being utilized for rescue operations, medical treatment, and entertainment imaging by emergency personnel, emergency medical services, and hobbyists [2]. UAVs are becoming widely used for non-military uses and are becoming an essential component of our culture.

The increasing use of UAVs raises concerns about safety and privacy [3]. Concerns about unlicensed and inexperienced pilots breaching prohibited zones and interfering with aircraft operations have arisen since recreational UAVs were allowed into national airspace. One aspect of the issue can be inadequate regulations while purchasing UAVs. The most concerning issue is the use of UAVs for terrorist attacks and illegal surveillance. To prevent the aforementioned occurrences, anti-UAV technology that can recognize, categorize, and destroy unauthorized UAVs gathering data using a variety of sensors is required. The introduction of machine learning (ML) algorithms has led to a rise in the popularity of UAV detection techniques among the scientific community. Several works have looked into how to recognize UAVs using ML algorithms in conjunction with various technical advancements including radar, audio, video, thermal imaging, RF, and video.

The advantages of RF-based technology over other UAV classification and detection systems are long-range detection and non-line-of-sight communication. Recently, there has been a significant surge in the use of ML algorithms for RF-based UAV identification and classification. Current research has focused on the detection and categorization of UAVs utilizing radiofrequency technology [4], [5]. In [4], the authors investigated RF-based UAV detection and recognition while accounting for interference from Bluetooth and WiFi wireless signals. They finished classification and detection tasks with varied levels of noise by utilizing principal component analysis in conjunction with many ML models, such as support

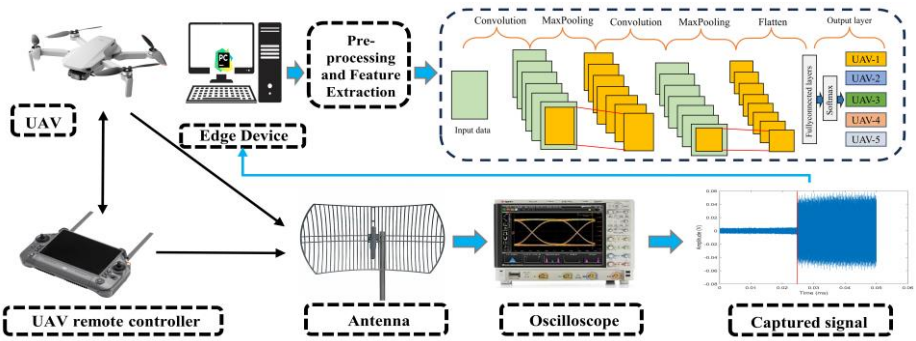

Fig. 1. The proposed framework of UAV classcification based on ML using RF signal.

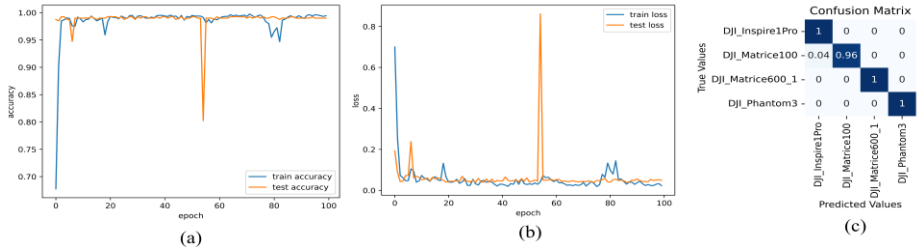

Fig. 2. Simulation results: (a) training and validation accuracy; (b) training and validation loss; (c) confusion matrix of the proposed model.

vector machine, k-nearest neighbors, and ensemble. In [5], the authors presented a DL method based on RF to classify multiple UAVs. To fulfill the detection and classification goals, the authors recommended the use of a supervised deep learning system. Inspired by the aforementioned works and the existing research gap, we have resolved a UAV detection and classification problem in this work by classifying Micro UAVs using RF signal analysis based on an ML-assisted CNN model.

The rest of the paper is organized as section II describes the methodology and proposed model, the outcomes of the simulation are illustrated in section II, and finally, the conclusion is represented in section III.

Ⅱ. Proposed Method and Simulation Results

The proposed system is shown in Fig. 1, where for this experiment, we used publicly available drone data. We used four drone RF signals and made them preprocessed for feeding into the proposed CNN model. The proposed model includes convolutional layers maxpolling layers, flatten layers, and output layers. After successful training of the model using RF drone data, the model can predict the four drone data efficiently. We have shown the training and validation accuracy and loss while learning the model using both sets of classes to assess the proposed model's training and validation. Fig. 2 (a), (b) displays the accuracy and loss for training and validation. As can be observed from Fig. 2 (a) and (b), the model for the four classes case reached a validation accuracy of 99% after completing 100 epochs, and the loss was reduced correspondingly. The confusion matrix results for the four classes case are displayed in Fig. 2 (c). The data demonstrate that, except for a small amount of misclassification, the suggested model demonstrated true and projected values of nearly 100% for each of the drone classes DJIInspire1Pro, DJIMatrice100, DJIMatrice6001, and DJIPhantom3.

III. Conclusion

In this work, we proposed an RF signal-based ML system for UAV classifictaion. CNN model is used to the configuration of the model. Grayscale values are used in place of RGB channels for feature extraction from RF signals from various drones. The simulation study makes use of the DroneRC datasets. The RF signal is prepossessed using the STFT before being used to train ML models. The suggested ML model offers good classification accuracy, according to simulation findings.

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* Corresponding author: Hyoung-Kyu Song

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