ABSTRACT

for the dissertation work on the topic:

“Research of effective UAV detection using acoustic data recognition”

submitted for the degree of Doctor of Philosophy (PhD) in specialty "6D071900 - Radio engineering, electronics and telecommunications"

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General characteristics of the work. The proposed dissertation investigates the development of an Unmanned Aerial Vehicles (UAV) detection system based on the acoustic data recognition. The recognition of UAV acoustic signals was conducted using Melspectrogram frequency characteristics and studied using Gated Recurrent Neural Network based neural architecture.

Relevance of the work. In recent years, Unmanned Aerial Vehicles have become widespread and have become very popular. The use of these small devices, also called drones, is increasing day by day, especially for purposes such as children's toys, adult recreational entertainment, photography, video surveillance in hard-to-reach places, agronomy, military intelligence, delivery, and transportation. Its increased technological capacity, including longer flight times, the ability to take flexible photos and videos from a variety of angles, and the opportunity for unfettered entry into different zones, is the primary factor behind their increased use by people. Also, over the past decade, the mass manufacturing of unmanned aerial vehicles (UAVs) at affordable prices has led to the problem of continuous use of these vehicles for various dubious and recreational purposes. The use of these vehicles carelessly or destructively puts individuals, their lives, protected institutions, and international borders in danger. These justifications take into account the fact that UAVs are becoming increasingly hazardous. As well as, there have been incidents with drones at the borders and territories of strategic buildings in the country. Moreover, drones used for recreational purposes and as children's toys have caused significant damage around the world. That is, there are many cases of damage caused by improper management. Overall, the reasons why the sustainable use of these vehicles is impossible and they are more thoroughly addressed in many research works. Thus, the high frequency of unauthorized drone flights requires the development of reliable real-time drone detection systems for protected areas. Therefore, these detection systems for the unauthorized use of UAVs are becoming more and more *relevant.* Particularly in the buildings of establishments such as kindergartens, hospitals, universities, administrations, ministries, border regions of the nation, protected territories where military bases are situated, reservoirs that shield major cities from snowmelt, and agricultural areas. In order to stop the proliferation of unlicensed drones in restricted and protected key

regions, there has been an increasing demand for research into security measures based on drone detection systems. Generally, in the UAV research and development (R&D) market, the Drone Detection System is being studied based on the following four main methods: Radar reconnaissance, Camera-based detection, RF signal processing, and Acoustic Sensor listening Detection. The aforementioned drone incidents require the preparation of a recognition system, including the recognition of their position, load states and models during flight according to their protection zones. That is why the intellectual acoustic sensor method is *relevant* due to its technical capabilities for recognizing such extended objectives.

The goal of the research. The goal of this thesis is to investigate an efficient recognition method of UAV Acoustic Data.

The Objectives of the research. In the studies of this dissertation, three main objectives are set:

1. Preparation and adaptation of UAV acoustic data and their various states.
2. Develop an efficient real-time system that integrates the acoustic signal processing step into the deep learning architecture.
3. Explore UAV acoustic data recognition using deep learning networks such as CNN, SimpleRNN, LSTM, BiLSTM and GRU.

In the first objective, UAV sounds were recorded in different states such as "Unloaded" and "Loaded". The sounds of the loaded UAVs were recorded in the state when they had a payload during the flight with different weights. The sounds of the environment in various scenarios and objects with increased motor noise were recorded as “background noise”. Various series of UAV models were also recorded.

At the second objective, the processing of UAV acoustic signals was combined into the architecture of deep learning networks.

In the third objective, deep learning algorithms were studied. In particular, all types of recurrent neural networks such as SimpleRNN, LSTM, BiLSTM and GRU. These neural networks have been investigated and applied to UAV sound detection. A comparative analysis of CNN and GRU networks was also carried out, as a result, the advantage of the GRU network for recognizing UAV acoustic data was determined.

Methods of the research. The research of this thesis was carried out on the basis of a combination of analytical and empirical methods. In particular, the experimental approach was employed to collect UAV sounds for the study's first objective. Additionally, Fast Fourier analysis, Short-Time Fourier Transform and Mel spectrogram filters were employed to analyze the audio signals that were gathered. Moreover, the Convolutional Neural Networks (CNNs) and Recurrent Neural networks (RNNs) deep learning methods were extensively used to achieve the last objective.

The scientific novelty of the work.

The novelty of this study is to development of an architecture of a UAV acoustic data recognition system with the integration of a modified Melspectrogram.

The theoretical and practical significance of the work. In this dissertation work, types of recurrent neural networks for recognition of UAV acoustic data were extensively investigated. The proposed system is recommended for national security systems, in particular the security of people, densely populated areas, airports, government buildings, kindergartens, schools, universities, national borders, customs and strategic places.

The validity and reliability of scientific provisions, conclusions and recommendations were confirmed by publications in journals included in the list of scientific publications recommended by the Committee for Control in Education and Science of the Ministry of Education and Science of the Republic of Kazakhstan, and to the Web of Science and Scopus database; approbation in a foreign international scientific and practical conference.

Approbation of the dissertation work. The main provisions of this dissertation work were reported and discussed at the conference “2020 Fourth IEEE International Conference on Robotic Computing (IRC), (Taichung, 2020. – P. 453-458)”.

Structure and scope of the thesis.

This dissertation consists of 5 parts: "State of the art: UAV detection with acoustic data", " UAV acoustic data preparation", "Mathematical view on the signal pre-analysis step in time and frequency domains", “Deep Learning methods for UAV acoustic data recognition” and "Real-time UAV acoustic data recognition and classification system".