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A COMBINED METHOD FOR RECOGNIZING AND INTERCEPING UNMANNED AERIAL VEHICLES USING MACHINE LEARNING METHODS

The widespread use of unmanned aerial vehicles (UAV) in high-intensity conflicts has become a standard tactic for conducting combat operations. Having relatively low production costs, the massive use of such means allows you to exhaust the country's air defense system at its various levels, spending small resources on such attacks compared to the cost of defense equipment. When performing such tasks, drones mainly attack critical infrastructure facilities, with the aim of undermining the country's economy.

Due to the imperfection of navigation systems and guidance accuracy, such aircraft very often hit civilian objects, which leads to great destruction and casualties among the civilian population. As a rule, attacks on critical infrastructure occur in the dark in order to improve visual search for targets and their destruction.

Unmanned aerial vehicles also solve the task of searching for short-range army air defense systems on the front line to destroy them and create unimpeded conditions for the use of attack aircraft and fighter-bombers [1]. That is why the issue of developing cheap systems for detecting such unmanned aerial vehicles is a relevant scientific and technical issue, which the authors are considering as part of their research.

The detailed study [2] conducted by the authors of the basic principles and methods of combating unmanned aerial vehicles allowed them to draw conclusions regarding possible ways of developing anti-drone systems and building systems for their detection and interception. As was found in the aforementioned study, only combining technologies such as radar, RF detection, cameras (EO), LIDAR (Light Detection and Ranging), and acoustic sensors, ensures allows building an effective

anti-drone system. Each component addresses different aspects of the threat, collectively creating a resilient defense system.

The construction of Anti-drone or counter-UAS (C-UAS, Counter-Unmanned Aircraft Systems) technology is considered as a combination of different approaches of artificial intelligence technologies. The initial assumptions of the study were the following parameters:

- flight altitude on the route to the target: 700 – 2000 m., with a decrease in the area of the target to 200 m.;
- flight speed to the target: 80 – 180 km/h;
- attack time: dark time of day.

In some cases, light-class UAVs are a difficult target for existing radars. These devices have a small effective scattering area, which makes their detection quite difficult. In particular, the maximum detection range is reduced. Small UAVs are characterized by small geometric dimensions, low thermal contrast, and flight speed, as well as a small effective scattering plane, which does not allow them to ensure sufficient effectiveness in defeating air defense systems [3].

That's why the research involves a combination of acoustic and optoelectronic sensors to detect enemy drones (fig.1).

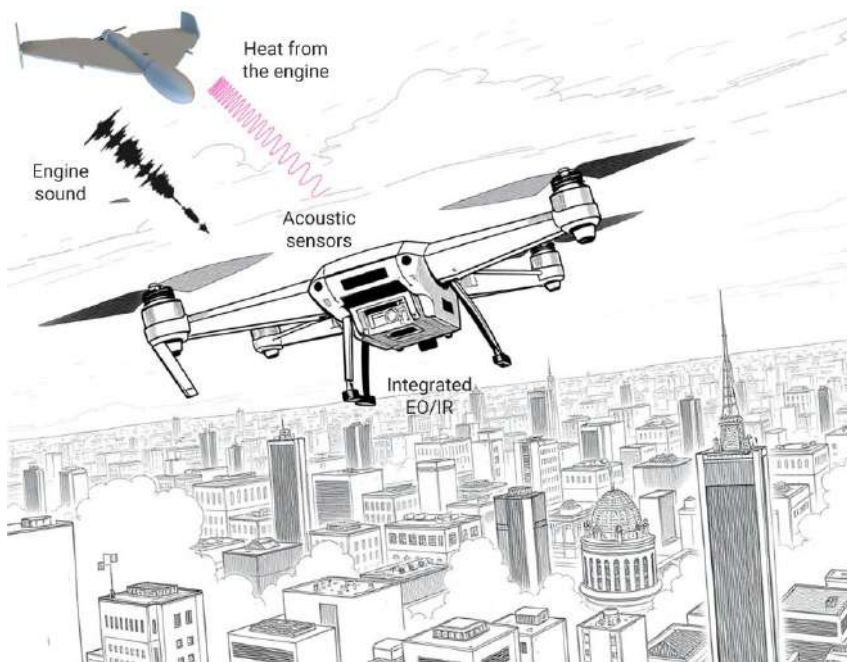


Figure 1 – Combined method of UAV recognition

Acoustic sensors involve a microphone or microphone set to detect the sound made by a drone and calculate its direction [4]. This method of detecting drones is especially relevant at night, when visual detection of targets is very difficult. Acoustic sensors, along with having a large number of advantages (rapid deployment, detection of drones in passive mode, detection at low altitudes), have a number of significant disadvantages, the main of which is poor efficiency in a noisy environment. That is why machine learning algorithms must distinguish between ambient noise of various types, as well as the sounds of the own engine, due to the location of sensors on the interceptor drone.

Optical sensors operate in the visible and infrared wavelength range, allowing drone detection day and night. Optical sensors are included in the operation at distances that allow for clear target acquisition after its identification and guidance using acoustic sensors at the previous stage.

The research involves several stages, the first of which is the development of a convolutional neural network to identify an enemy drone using the sound emitted by its engine. To build a system that can recognize when a particular sound is happening - a task known as audio classification. The next stages involve the research and construction of machine learning algorithms to identify, track, and destroy an enemy drone using optoelectronic sensors.

To build a sound classification model for a Shahed drone, the research used a training dataset that included the following sound tracks:

- sound tracks with ambient sounds or Background noise (data class 1), including small arms fire and wind at certain flight altitudes.
- sound tracks directly from the Shahed flight (data class 2), which also included both the pure sound of the engine and the sound of the engine against the background of small arms fire (machine guns, machine guns, cannon).

The total duration of the sound tracks was 15 minutes.

MFE (Mel Frequency Energy) signal processing block was used to turn raw audio – which contains a large amount of redundant information into simplified form (fig.2) [5]. Then this simplified audio data were passed into a Neural Network block, which will learn to distinguish between the two classes of audio (Background noise and Shahed flight).

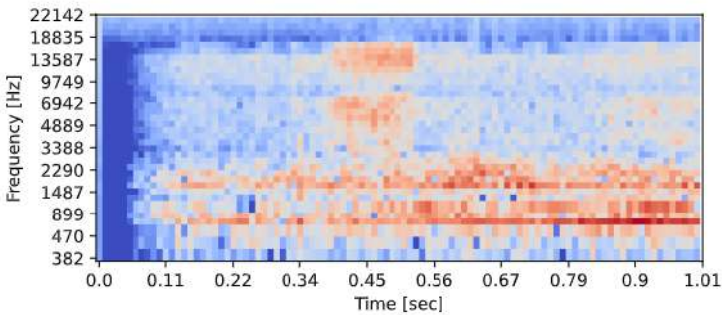


Figure 2 – Spectrogram. MFE's output for a piece of real Shahed's engine sound

At the start of training, 20% of the training data is set aside for validation. The Last training performance panel (fig.3) displays the results of this validation.

Last training performance (validation set)



Figure 3 – Last training performance panel

The results of testing the model on test sets of sounds of Shahed drone engines suggest the prospects for further research in the direction of optimizing model parameters and involving a larger number of training datasets in order to improve model accuracy (fig.4).

	NOISE	SHAHED	UNCERTAIN
NOISE	-	-	-
SHAHED	15.4%	84.6%	0%
F1 SCORE	0.00	0.92	

Figure 4 – Confusion matrix

Further research involves improving the classification model at the first stage of drone identification, developing an algorithm for approaching the target using acoustic sensors at night, and switching to guidance using optoelectronic sensors at the final stage of pursuit and destruction.

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