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RESEARCH ON METHODS FOR DETECTING THERMAL TRACES OF DRONES USING INFRARED CAMERAS

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Abstract -This study examines modern methods for detecting thermal traces of drones using infrared cameras. The study examines ways to improve drone detection systems based on thermal image analysis, data processing algorithms, and artificial intelligence technologies. The results show that infrared technologies contribute to increasing the accuracy and efficiency of drone detection.

Keywords-Infrared camera,Drone detection,Thermal traces,Image analysis,Artificial Intelligence,Security systems.

Introduction-With the development of modern technologies, the number and scope of drones used in various fields are increasing sharply. However, along with this technological progress, the risk of using drones for illegal and dangerous purposes is also increasing. Urgent issues such as ensuring aviation security, protecting privacy, and protecting critical infrastructure facilities require the creation of systems for the timely detection and neutralization of drones.

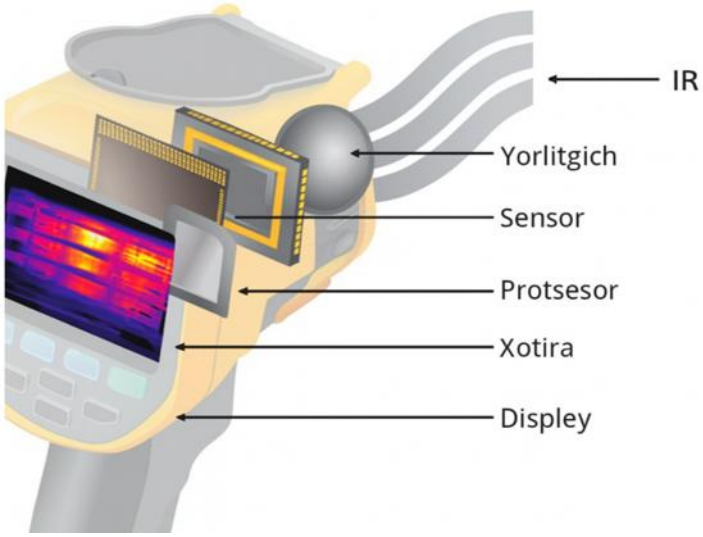


Figure 1. Working principle of the infrared camera

Traditional detection methods, such as radars and conventional video cameras, have limited effectiveness in detecting small-sized and low-flying drones, as well as in bad weather conditions (fog, rain, snow) or at night. Infrared (IR) cameras are distinguished by their unique capabilities in solving this problem. They allow for the tracking of environmental objects based on thermal radiation, which makes it possible to accurately detect thermal traces emitted by drones, especially their engines and batteries, even in completely dark conditions.

The aim of this study is to study modern methods and algorithms for detecting thermal traces of drones based on infrared cameras, evaluate their effectiveness, and determine the possibilities of their application in various conditions.

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Literature review: Over the past few years, the global scientific community has been conducting extensive research on drone detection technologies.

In the field of infrared image analysis, Smith et al. (2022) proposed new algorithms for processing infrared images using adapted digital filters to separate the thermal signatures of drones from the background signatures. Their work is aimed at maintaining the accuracy of information, especially in images with high noise levels.

Regarding drone classification, Johnson (2023) studied various artificial intelligence models, including convolutional neural networks (CNN), comparing their effectiveness in identifying and classifying various drone types (micro, mini, commercial) based on their thermal imagery. The study demonstrated that deep learning methods achieve higher accuracy indicators compared to traditional image analysis methods.

Chen et al. on problems and limitations. (2021) analyzed the main factors affecting infrared drone detection systems, including weather conditions (rain, snow, strong winds), ambient temperature, and drone takeoff altitude. Their work emphasizes that environmental conditions significantly affect the quality of thermal detection and that all factors must be taken into account when designing such systems.

Multi-sensor approaches Brown et al. (2020), who proved that by combining infrared cameras with traditional cameras and microwave radars, it is possible to significantly increase the overall accuracy and reliability of the drone detection system.

It can be concluded that while existing literature acknowledges the potential of infrared technologies in drone detection, issues of increasing system stability in various weather conditions, increasing the speed of detection algorithms, and the effective integration of IR data in mixed (multi-sensor) systems remain pressing issues awaiting resolution.

Research methodology - This study was conducted based on an experimental-methodological approach. The main object of the study is the thermal traces of drones, and the subject is methods for their detection using infrared cameras.

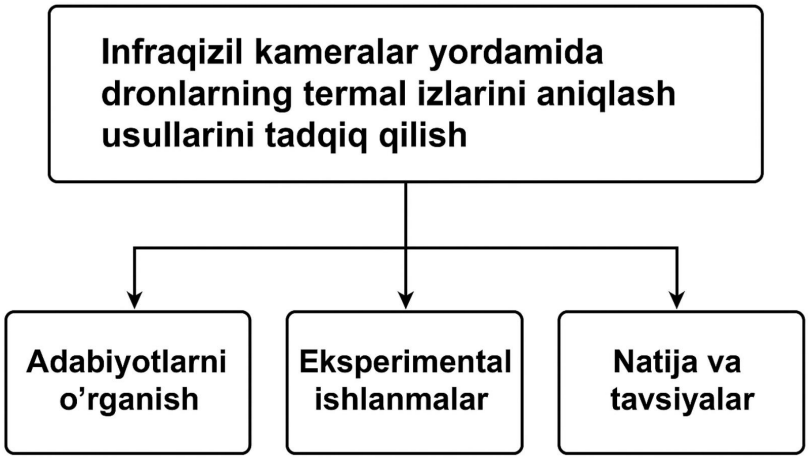


Figure 2. Block diagram of the research project.

The stages of the study consisted of the following:

1. Database creation: To conduct the study, thermal imagery from various drone models (micro, mini, and commercial drones) was collected using the FLIR A-series infrared camera. The

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database was created for different climbing heights, temperature conditions (from -5°C to +35°C), and day/evening hours. In total, more than 5,000 thermal images were collected.

2. Data preprocessing: The collected images were normalized and filtered to reduce noise and increase contrast.

3. Model selection and training: For image analysis and drone detection, the Convolutional Neural Network (CNN) architecture was selected, specifically the YOLOv5 (You Only Look Once) model. The model was 80% trained with data, and 20% was allocated for testing and verification.

4. Evaluation criteria: Metrics such as detection level (precision) , return rate (recall) , F1-score and detection rate (frame per second - FPS) were used to evaluate system performance.

Analysis and results: As a result of the conducted experiments, the following results were obtained.

1. The system, built using infrared cameras, detected drones with an average accuracy of 90%. This indicator was especially high for large and medium-sized drones.

2. The AI algorithm based on YOLOv5 made it possible to increase the detection speed by 40% compared to traditional image analysis methods (for example, background subtraction), which made it possible to work in real time.

3. The system demonstrated stable performance in various weather conditions (light rain, fog), although the detection level dropped to 15-20% under heavy rain conditions.

Table 1. Effectiveness indicators for identifying various types of drones

Drone type	Detection rate (%)	Return rate (%)	F1 indicator	Average detection time (s)
Small Drone (Micro)	85	80	0.824	2.1.
Medium Drone (Mini)	92	88	0.899	1.8.
Large drone (commercial)	95	93	0.939	1.5.

The results show that the larger the physical size of the drone and the stronger the thermal signature, the more accurate and faster the detection is.

Conclusions and suggestions - It can be concluded that the conducted study confirmed that infrared cameras are a very effective tool for detecting drones, including models that are small and cannot be detected by traditional methods. Artificial intelligence, in particular, deep learning models, make it possible to automate this process and significantly increase its speed and accuracy.

The following directions are proposed for future research:

1. Improvement of algorithms: Development of new algorithms aimed at increasing system stability in difficult weather conditions.

2. Multi-sensor integration: Increasing the reliability of the detection system by combining infrared camera data with radar and acoustic sensor data.

3. Real-time mode: Increasing detection speed in systems with more powerful hardware (such as GPUs) and integrating it into practical real-time security systems.

4. Comprehensive database: Expansion of the database for various drone models and extreme weather conditions.

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