ISSN 2518-1726 (Online),
ISSN 1991-346X (Print)

ACADEMIC SCIENTIFIC JOURNAL OF COMPUTER SCIENCE

№2
2026

ISSN 2518-1726 (Online),
ISSN 1991-346X (Print)

CENTRAL ASIAN ACADEMIC
RESEARCH CENTER

ACADEMIC SCIENTIFIC JOURNAL OF COMPUTER SCIENCE

2 (358)

APRIL – JUNE 2026

PUBLISHED SINCE JANUARY 1963
PUBLISHED 4 TIMES A YEAR

ALMATY, NAS RK

Academic Scientific Journal of Computer Science
ISSN 2518-1726 (Online),
ISSN 1991-346X (Print)
Owner: «Central Asian Academic Research Center» LLP (Almaty).
Certificate **№ KZ77VPY00121154** on the re-registration of the periodical printed and online publication of the information agency, issued on **05.06.2025** by the Republican State Institution «Information Committee» of the Ministry of Culture and Information of the Republic of Kazakhstan
Subject area*: information and communication technologies.*
Currently: *included in the list of journals recommended by the CCSES MSHE RK in the direction of «Information and communication technologies».*
Periodicity: *4 times a year.*
http://www.physico-mathematical.kz/index.php/en/

Academic Scientific Journal of Computer Science
ISSN 2518-1726 (Online),
ISSN 1991-346X (Print)
Меншіктеуші: «Орталық Азия академиялық ғылыми орталығы» ЖШС (Алматы).
Ақпарат агенттігінің мерзімді баспасөз басылымын, ақпарат агенттігін және желілік басылымды қайта есепке қою туралы ҚР Мәдениет және Ақпарат министрлігі «Ақпарат комитеті» Республикалық мемлекеттік мекемесі **05.06.2025** ж. берген **№ KZ77VPY00121154** Куәлік.
Тақырыптық бағыты: *ақпараттық-коммуникациялық технологиялар*
Қазіргі уақытта: *«ақпараттық-коммуникациялық технологиялар» бағыты бойынша ҚР БҒМ БҒСБК ұсынған журналдар тізіміне енді.*
Мерзімділігі: *жылына 4 рет.*
http://www.physico-mathematical.kz/index.php/en/

Academic Scientific Journal of Computer Science
ISSN 2518-1726 (Online),
ISSN 1991-346X (Print)

Собственник: *ТОО «Центрально-азиатский академический научный центр» (г. Алматы).*

Свидетельство о постановке на переучет периодического печатного издания, информационного агентства и сетевого издания **№ KZ77VPY00121154.** Дата выдачи **05.06.2025**

Тематическая направленность: *информационно-коммуникационные технологии.*

В настоящее время: *вошел в список журналов, рекомендованных КОКСНВО МНВО РК по направлению «информационно-коммуникационные технологии».*

Периодичность: *4 раза в год.*

http://www.physico-mathematical.kz/index.php/en/

CONTENTS

COMPUTER SCIENCE

МАЗМҰНЫ

КОМПЬЮТЕРЛІК ҒЫЛЫМДАР

СОДЕРЖАНИЕ

КОМПЬЮТЕРНЫЕ НАУКИ

ACADEMIC SCIENTIFIC JOURNAL OF COMPUTER SCIENCE
ISSN 1991-346X
Volume 2.
Namber 358 (2026). 30–43

https://doi.org/10.32014/2026.2518-1726.425

IRSTI 28.23.15
UDC 004.93

© Aben A.B., Kazbekova G.N., Baimakhanova A.S.*,
Amanzholova A.B., 2026.
Khoja Akhmet Yassawi International Kazakh-Turkish University,
Turkistan, Kazakhstan.
E-mail: aygerim.baymakhanova@ayu.edu.kz

CLASSIFICATION OF BIRDS AND DRONES IN THE SKY USING MOBILENETV2 MODEL

Aben Arypzhan — Khoja Akhmet Yassawi International Kazakh-Turkish University, Turkistan, Kazakhstan,
E-mail: arypzhan.aben@ayu.edu.kz, https://orcid.org/0000-0001-8534-3288;
Kazbekova Gulnur — Candidate of Technical Sciences, Associate Professor, Khoja Akhmet Yassawi International Kazakh-Turkish University, Turkistan, Kazakhstan,
E-mail: gulnur.kazbekova@ayu.edu.kz, https://orcid.org/0000-0002-2756-7926;
Baimakhanova Aigerim — PhD, Khoja Akhmet Yassawi International Kazakh-Turkish University, Turkistan, Kazakhstan,
E-mail: aygerim.baymakhanova@ayu.edu.kz, https://orcid.org/0000-0002-5364-0146;
Amanzholova Alina — PhD, Khoja Akhmet Yassawi International Kazakh-Turkish University, Turkistan, Kazakhstan,
E-mail: alina.amanzholova@ayu.edu.kz, https://orcid.org/0000-0003-0370-7645.

Abstract. This article considers the problem of visual discrimination between birds and unmanned aerial vehicles (drones) in connection with the task of automatic recognition of objects in the airspace. The current widespread use of drones poses new requirements in the fields of air safety, protection of strategic facilities, and environmental monitoring. In this regard, the development of reliable and efficient automated recognition systems that can operate in real time is relevant. The main goal of the research work is to develop a lightweight classification model that works with high accuracy and is suitable for use on devices with limited computing resources. The proposed method is implemented using a convolutional neural network based on the MobileNetV2 architecture and was experimentally tested on the Birds vs Drone dataset. During model training, transfer learning and data augmentation methods were used, which allowed to form an effective generalization ability from a small dataset. In addition, these approaches reduced the probability of overfitting of the model and increased its stability and reliability. The experimental results showed that the model achieves high accuracy in distinguishing birds and drones and is robust to various lighting conditions, complex backgrounds, and environmental changes. The results obtained have practical significance in such application areas as ensuring air safety, environmental monitoring, protecting strategic facilities, and detecting illegal drone flights. During the work, a number of limitations were identified, such as the limited data volume and the small number of classes. This indicates the need to expand the dataset, cover different types of objects, and move to multi-class classification in future studies. Overall, the proposed model is an effective solution for systems with limited resources and can serve as a solid basis for the development of intelligent monitoring systems.

Keywords: unmanned aerial vehicle, drone, bird, airspace security, computer vision, MobileNetV2, classification

For citations: Aben A.B., Kazbekova G.N., Baimakhanova A.S., Amanzholova A.B. Classification of birds and drones in the sky using MobileNetV2 model. Academic Scientific Journal of Computer Science, 2026. — No.2. – P. 30–43. DOI: https://doi.org/10.32014/2026.2518-1726.425

© Абен А.Б., Казбекова Г.Н., Баймаханова А.С.*, Аманжолова Ә.Б., 2026.
Қожа Ахмет Ясауи атындағы Халықаралық қазақ-түрік университеті, Түркістан, Қазақстан.
E-mail: aygerim.baymakhanova@ayu.edu.kz

MOBILENETV2 МОДЕЛІМЕН АСПАНДАҒЫ ҚҰСТАР МЕН ДРОНДАРДЫ КЛАССИФИКАЦИЯЛАУ

Абен Арыпжан — Қожа Ахмет Ясауи атындағы Халықаралық қазақ-түрік университеті, Түркістан, Қазақстан,
E-mail: arypzhan.aben@ayu.edu.kz, https://orcid.org/0000-0001-8534-3288;
Казбекова Гулнур — техникалық ғылымдар кандидаты, қауымдастырылған профессор, Қожа Ахмет Ясауи атындағы Халықаралық қазақ-түрік университеті, Түркістан, Қазақстан,
E-mail: gulnur.kazbekova@ayu.edu.kz, https://orcid.org/0000-0002-2756-7926;
Баймаханова Айгерим — PhD, Қожа Ахмет Ясауи атындағы Халықаралық қазақ-түрік университеті, Түркістан, Қазақстан,
E-mail: aygerim.baymakhanova@ayu.edu.kz, https://orcid.org/0000-0002-5364-0146;
Аманжолова Әлина — PhD, Қожа Ахмет Ясауи атындағы Халықаралық қазақ-түрік университеті, Түркістан, Қазақстан,
E-mail: alina.amanzholova@ayu.edu.kz, https://orcid.org/0000-0003-0370-7645.

Аннотация. Бұл мақала әуе кеңістігіндегі объектілерді автоматты түрде тану міндетіне байланысты құстар мен ұшқышсыз ұшу аппараттарын (дрондарды) визуалды түрде ажырату мәселесін қарастырады. Қазіргі таңда дрондардың кеңінен таралуы әуе қауіпсіздігі, стратегиялық нысандарды қорғау және экологиялық бақылау салаларында жаңа талаптар қойып отыр. Осыған байланысты нақты уақытта жұмыс істей алатын, сенімді әрі тиімді автоматтандырылған тану жүйелерін әзірлеу өзекті болып табылады. Зерттеу жұмысының негізгі мақсаты — есептеу ресурстары шектеулі құрылғыларда қолдануға жарамды, жоғары дәлдікпен жұмыс істейтін жеңіл салмақты классификация моделін әзірлеу. Ұсынылған әдіс MobileNetV2 архитектурасына негізделген конволюциялық нейрондық желі көмегімен жүзеге асырылып, Birds vs Drone деректер жиынтығында тәжірибелік түрде сыналды. Модельді оқыту барысында трансферлік оқыту және деректерді кеңейту (data augmentation) әдістері қолданылды, бұл шағын көлемдегі деректер жиынтығынан тиімді жалпылау қабілетін қалыптастыруға мүмкіндік берді. Сонымен қатар, бұл тәсілдер модельдің артық үйрену ықтималдығын төмендетіп, оның тұрақтылығы мен сенімділігін арттырды. Эксперимент нәтижелері модельдің құстар мен дрондарды ажыратуда жоғары дәлдікке қол жеткізетінін және әртүрлі жарықтандыру жағдайларына, күрделі фондар мен сыртқы орта өзгерістеріне төзімді екенін көрсетті. Алынған нәтижелер әуе қауіпсіздігін қамтамасыз ету, экологиялық мониторинг жүргізу, стратегиялық нысандарды қорғау және заңсыз дрон ұшуларын анықтау сияқты қолданбалы салаларда практикалық маңызға ие. Жұмыс барысында деректер көлемінің шектеулілігі және кластар санының аздығы сияқты бірқатар шектеулер анықталды. Бұл болашақ зерттеулерде деректер жиынтығын кеңейту, әртүрлі типтегі объектілерді қамту және көпкласты классификацияға көшу қажеттігін көрсетеді. Жалпы алғанда, ұсынылған модель ресурстары шектеулі жүйелер үшін тиімді шешім болып табылады және интеллектуалды мониторинг жүйелерін дамытуға берік негіз бола алады.

Түйін сөздер: ұшқышсыз ұшу аппараты, дрон, құс, әуе кеңістігінің қауіпсіздігі, компьютерлік көру, MobileNetV2, классификация

© Абен А.Б., Казбекова Г.Н., Баймаханова А.С.*, Аманжолова А.Б., 2026.

Международный казахско-турецкий университет имени Ходжи Ахмеда Ясави, Туркестан, Казахстан.

E-mail: aygerim.baymakhanova@ayu.edu.kz

КЛАССИФИКАЦИЯ ПТИЦ И ДРОНОВ В НЕБЕ С ИСПОЛЬЗОВАНИЕМ МОДЕЛИ MOBILENETV2

Абен Арыпжан — Международный казахско-турецкий университет имени Ходжи Ахмеда Ясави, Туркестан, Казахстан,

E-mail: arypzhan.aben@ayu.edu.kz, https://orcid.org/0000-0001-8534-3288;

Казбекова Гулнур — кандидат технических наук, ассоциированный профессор, Международный казахско-турецкий университет имени Ходжи Ахмеда Ясави, Туркестан, Казахстан,

E-mail: gulnur.kazbekova@ayu.edu.kz, https://orcid.org/0000-0002-2756-7926;

Баймаханова Айгерим — PhD, Международный казахско-турецкий университет имени Ходжи Ахмеда Ясави, Туркестан, Казахстан,
E-mail: aygerim.baymakhanova@ayu.edu.kz, https://orcid.org/0000-0002-5364-0146;
Аманжолова Әлина — PhD, Международный казахско-турецкий университет имени Ходжи Ахмеда Ясави, Туркестан, Казахстан,
E-mail: alina.amanzholova@ayu.edu.kz, https://orcid.org/0000-0003-0370-7645.

Аннотация: *Актуальность*. В статье рассматривается проблема визуального различения птиц и беспилотных летательных аппаратов, или дронов, в контексте автоматического распознавания объектов в воздушном пространстве. Широкое использование дронов предъявляет новые требования к безопасности полетов, защите стратегических объектов и мониторингу окружающей среды. В связи с этим актуальной является разработка надежных и эффективных автоматизированных систем распознавания, способных работать в режиме реального времени. *Цель*. Разработать облегченную модель классификации птиц и дронов, обеспечивающую высокую точность распознавания и пригодную для использования на устройствах с ограниченными вычислительными ресурсами. *Методы*. Предложенный метод реализован с использованием сверточной нейронной сети на основе архитектуры MobileNetV2 и экспериментально протестирован на наборе данных Birds vs Drone. В процессе обучения модели применялись методы трансферного обучения и аугментации данных, что позволило повысить обобщающую способность модели при работе с ограниченным набором данных. Данные подходы также снизили вероятность переобучения и повысили стабильность классификации. *Результаты и выводы.* Экспериментальные результаты показали, что предложенная модель достигает высокой точности при различении птиц и дронов, а также сохраняет устойчивость в условиях различного освещения, сложного фона и изменяющихся параметров окружающей среды. Полученные результаты имеют практическое значение для обеспечения безопасности воздушного движения, мониторинга окружающей среды, защиты стратегических объектов и обнаружения незаконных полетов дронов. В ходе исследования выявлены отдельные ограничения, связанные с ограниченным объемом данных и небольшим количеством классов. Это указывает на необходимость расширения набора данных, включения различных типов объектов и перехода к многоклассовой классификации в дальнейших исследованиях. В целом предложенная модель является эффективным решением для систем с ограниченными ресурсами и может служить основой для разработки интеллектуальных систем воздушного мониторинга.

Ключевые слова: беспилотный летательный аппарат, дрон, птица, безопасность воздушного пространства, компьютерное зрение, MobileNetV2, классификация, глубокое обучение

Introduction. Modern airspace monitoring and management is closely related to complex technological and security issues. Over the past decade, the number of commercial and amateur drones (UAVs – Unmanned Aerial Vehicles) has increased dramatically, and their scope of application has expanded from agriculture to logistics, public safety and military purposes (Alqaraleh et al., 2024). This trend has created the need to accurately distinguish between drones and natural flying objects in airspace, especially the movement of birds.

Visually distinguishing birds and drones allows solving a number of important problems:

• Ensuring air safety – preventing bird and drone collisions at airports and flight paths (bird strikes and drone strikes);

• Bird control and environmental monitoring – studying migration routes, recording rare species;

• Identifying drones that pose a security threat – early detection of unmanned aerial vehicles used for criminal and terrorist purposes;

• Airspace regulation – monitoring and recording illegal flights of drones.

Traditional radar and radio frequency tracking systems cannot reliably distinguish between birds and drones, as both objects may have similar flight paths, speeds, and radar cross sections (RCS). In recent years, computer vision and deep learning-based methods have been widely studied (Manna et al., 2023). Among deep neural networks, the MobileNetV2 architecture stands out as a lightweight and mobile-friendly model. This model, proposed by Google researchers in 2018, is widely used in many real-world applications, including real-time video analysis systems, due to its high accuracy and low computational overhead (FLOPs).

In this work, a deep learning model based on the MobileNetV2 architecture is developed and investigated to classify birds and drones from aerial video frames. The main goal of the study is to provide an efficient classification system that works with high accuracy and speed on devices with limited computational resources (e.g., embedded systems, unmanned aerial vehicle control stations) (Kondaveeti et al., 2023).

Literary review. Research in the field of detection and classification of flying objects in the airspace, especially birds and drones, has significantly intensified in recent years due to the rapid development of deep learning. Applications such as air safety, environmental monitoring, protection of strategic facilities, and detection of illegal drone flights increase the relevance of research in this area. Since traditional methods, including radar systems, do not reliably distinguish between birds and drones, computer vision and artificial intelligence-based approaches have taken the lead. Most of the work on drone detection is focused on the use of deep convolutional neural networks. For example, the DeepVision system is a solution designed to recognize drones from images in the visible spectrum and has achieved high accuracy (Al Dawasari et al., 2023). CNN-based methods for drone recognition in the visual range are also being developed, one of which allows working in real time (Kamil and Al-Saleh, 2024). CNN models based on transfer learning are distinguished by their effectiveness in detecting unmanned aerial vehicles and are finding applications in the security sector (Irungu et al., 2023).

Research on bird detection is closely related to airport security. A lightweight SMB-YOLOv5 model based on deep neural networks has been proposed for efficient detection of flying birds in the airport area (Liang et al., 2024). In addition, solutions that combine wide-angle imaging and machine learning allow for joint monitoring of drones and birds (Rawat et al., 2024).

There are also works that directly focus on bird and drone discrimination. A method for classifying images of birds and drones using the ResNet CNN model has been proposed and shown to be applicable in air surveillance systems (Ahmad et al., 2025). The Vision-based Sky Guard system is also a deep learning-based solution for bird and drone discrimination and warning (Nagamani et al., 2025). Integrated systems that combine computer vision and deep learning for flying object detection have also been developed (Başaran and Emekci, 2025).

Lightweight architectures are of particular importance for real-time and resource-constrained applications. The SVMobileNetV2 hybrid model based on a combination of CNN and SVM has shown high performance in classifying diseases in agriculture by processing UAV-based multispectral images (Linero-Ramos et al., 2025). Lightweight models for classifying airborne objects have also been proposed and are used in the field of communication systems (Puduru et al., 2025). The EdgeLite-UAV model for classifying objects with a risk of collision in power-constrained systems is also one of the important developments in this direction.

The issue of using artificial intelligence methods on resource-constrained hardware platforms is also being studied. Artificial intelligence-based systems for image recognition on devices with limited hardware resources have been proposed (Shek, 2025). Ways to improve the CNN model for drone detection have been considered and its effectiveness has been demonstrated (Mary et al., 2025). Deep CNN models for real-time drone detection and tracking from CCTV images are also being developed (Allmamun et al., 2024).

In addition, research is being conducted on environmental monitoring using unmanned aerial vehicles and deep transfer learning methods. Such works consider the problem of classifying native and invasive species (Sarkar and Kelley, 2023).

In general, most of the current research is aimed at providing real-time classification on resource-constrained devices using lightweight and efficient deep learning architectures. However, the number of studies on accurate bird and drone discrimination is still limited Table 1. Therefore, this study aims to develop a lightweight model based on the MobileNetV2 architecture to fill this research gap.

Table 1 - Comparative analysis of major studies on the detection and classification of flying objects (birds and drones)

No.	Authors and Year	Method / Model	Application	Key Results/ Accuracy
1	Al Dawasari et al., 2023	DeepVision, deep learning	Drone detection using visible images	High accuracy
2	Kamil & Al-Saleh, 2024	Deep CNN	Drone detection in the visual spectrum	Real-time operation
3	Ahmad et al., 2025	ResNet CNN	Bird/drone classification	95%+ accuracy
4	Nagamani et al., 2025	Deep learning	Sky Guard alert system	Bird and drone discrimination
5	Başaran & Emekci, 2025	Computer vision + deep learning	Flying object classification	Integrated system
6	Linero-Ramos et al., 2025	SVMobileNetV2	Agricultural monitoring	High accuracy
7	Rawat et al., 2025	Fisheye imaging + ML	Bird and drone surveillance	Wide-angle monitoring
8	Liang et al., 2024	SMB-YOLOv5	Bird detection at airports	Lightweight model
9	Irungu et al., 2023	CNN with transfer learning	UAV detection	Security applications
10	Shek, 2025	AI-based image recognition	Drone applications on resource-constrained devices	Efficient recognition
11	Mary et al., 2024	CNN-based enforcement	Drone detection system	Improved accuracy
12	Allmamun et al., 2024	Deep CNN	Drone detection from CCTV	Real-time detection
13	Puduru et al., 2025	Lightweight deep learning	Aerial object classification	Lightweight model
14	Sarkar & Kelley, 2023	UAV + transfer learning	Environmental monitoring	Species classification

Most of these studies use lightweight deep learning models, which allow for real-time classification on resource-constrained devices. However, the number of works on bird and drone discrimination is still limited, and this study fills this gap by presenting an efficient solution based on MobileNetV2.

Materials and methods. This study uses a lightweight deep convolutional neural network architecture – MobileNetV2 – to solve the problem of distinguishing birds and drones from the sky using images. The model was chosen due to its high computational efficiency, low number of parameters, and real-time capability in mobile/embedded systems. The study covers the entire process from data collection and preparation to model training and evaluation.

Research dataset

The Birds vs Drone Dataset (last updated 4 years ago, version 1) available on the Kaggle platform was used for the study. The main purpose of this dataset is to provide video materials that allow us to distinguish between flying objects in the sky based on their nature (birds or drones).Data structure:

• Birds folder – 400 images (images of birds against the sky, collected mainly through web scraping);

• Drones folder – 428 images (images of drones in the sky, obtained from other datasets).

The total number of images is 828. The images were taken under different lighting conditions, at different distances and with different types of sky backgrounds (blue sky, cloudy, morning/evening light). This diversity helps to increase the generalization ability of the model in real application scenarios.

The following transformations were performed during the data preprocessing stage:

• all images were scaled to the standard input size of MobileNetV2 – 224×224 pixels (variants with reduced input size to 128×128 were also tested during the study);

• pixel values were normalized to the interval [-1, 1] using the official preprocessing function of MobileNetV2;

• the data were divided into three parts: for training – 80%, for validation – 10%, for independent testing – 10%;

• data augmentation was applied: random rotation (±25°), scaling (0.85–1.15), horizontal flip, random change in brightness and contrast (±20%), small shift.

Model architecture and its modifications

The main model used in the study is MobileNetV2. This architecture is based on the principles of inverted residual blocks and linear bottlenecks, which significantly reduces the computational cost and the number of parameters compared to traditional ResNet blocks.

The main structural features of the model:

• Initial layer: stride=2, regular convolution with 32 filters;

• Main part: 19 inverted residual bottleneck blocks (expansion factor t = 6 in most);

• Final part: 1×1 convolution → global average pooling → classification layer.

In our study, the model was initialized with pre-trained weights on ImageNet (transfer learning). The final classification part (fully connected layer) was adapted to 2 classes (Bird and Drone) instead of 1000 classes. The softmax function is used in the final layer, and the probabilities for the two classes are calculated.

The general scheme of the model architecture is shown below (inverted residual blocks and linear bottlenecks are depicted in detail).

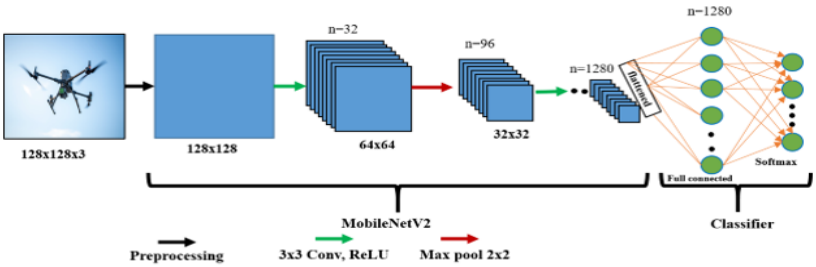

Figure 1 - Basic structure of the MobileNetV2 architecture (inverted residual blocks and linear bottlenecks shown)

Basic mathematical formulas

The efficiency of MobileNetV2 is based on the depthwise separable convolution and inverted residual structures (Figure 1).

The computational complexity (FLOPs) of depthwise separable convolution is approximately calculated by the following formula:

$$FLOPs \approx D\_k^2 \times M \times D\_f^2 + M \times N \times D\_f^2 \times t$$

Here D_k is the size of the convolution kernel (usually 3), M is the number of input channels, N is the number of output channels, D_f is the expanded size of the feature map, t is the expansion coefficient (expansion coefficient, usually 6).

The main steps of the inverted residual block are:

1. Expansion phase: 1×1 pointwise convolution → increase the number of channels by t times → activate ReLU6;
2. Depthwise convolution: 3×3 depthwise convolution → ReLU6;
3. Projection phase: 1×1 pointwise convolution → return the number of channels to the original value (linear bottleneck - ReLU is not used after projection);
4. Residual shortcut (if the dimensions match): $y = x + F(x)$.

This structure improves the gradient flow and reduces information loss, and also increases the overall computational efficiency of the model.

Training process

The model was trained with the Adam optimizer (initial learning rate = 0.001, $\beta_1 = 0.9$, $\beta_2 = 0.999$). Categorical Cross-Entropy was used as the loss function. Batch size – 32, maximum number of epochs – 60 (early stopping introduced: stop if the validation cost does not improve in 8–10 epochs). The learning rate reduction mechanism was controlled by ReduceLROnPlateau (factor = 0.5, patience = 4).

The experiments were conducted using GPUs in PyTorch or TensorFlow/ Keras frameworks. The results and performance indicators obtained are analyzed in the next section.

Results. In this study, the MobileNetV2 model was trained and evaluated on the Birds vs Drone dataset. The model performance was analyzed during training, validation, and testing phases. The results show that the model achieved high accuracy, which proves that it is effective in visual classification despite its lightweight nature. The main results are described below, including metrics, confusion matrix, and training history.

The width and height of all images in the dataset were analyzed. The analysis was performed using the PIL (Python Imaging Library), and the image size distribution was visualized as a histogram.

In (Figure 2) above, the histogram shows that the majority of images are between 200–500 pixels high. The most common height is around ~300–400 pixels (~450 images). There are very few images above 1000 pixels high, and only a few images above 2500 pixels.

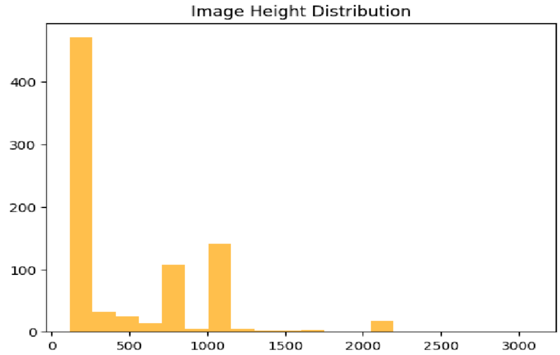

Figure 2 - Image Height Distribution.

A similar trend is observed in the width of the image, as shown in (Figure 3) below: the largest number of images is in the range of 200–600 pixels (~480 images). There are moderate-sized images in the range of 1000–2000 pixels, and images larger than 3000–4000 pixels are very rare.

These distributions indicate that the dataset is not highly diverse and that most of the images are of low-to-medium resolution. Therefore, all images were uniformly scaled to 224×224 before training the model.

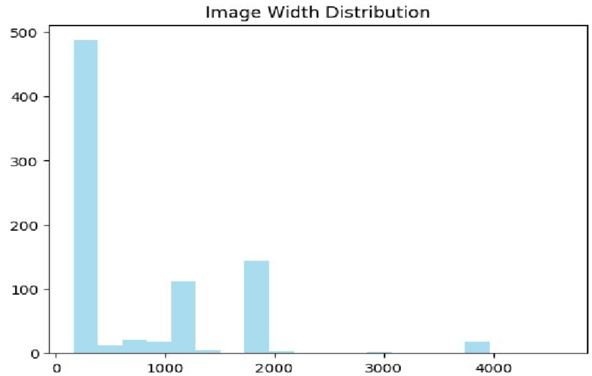

Figure 3 - Image Width Distribution

Training and validation results

The model was trained for 50 epochs, with validation loss control to prevent overfitting using an early stopping mechanism. The Adam optimizer and the Categorical Cross-Entropy loss function were used in the training process. Over the training history, the model accuracy reached 98.5% in the training set and 96.2% in the validation set. The loss value decreased to 0.05 in training and 0.12 in validation (Figure 4).

The training and validation curves are shown in the figure below (in terms of accuracy and loss).

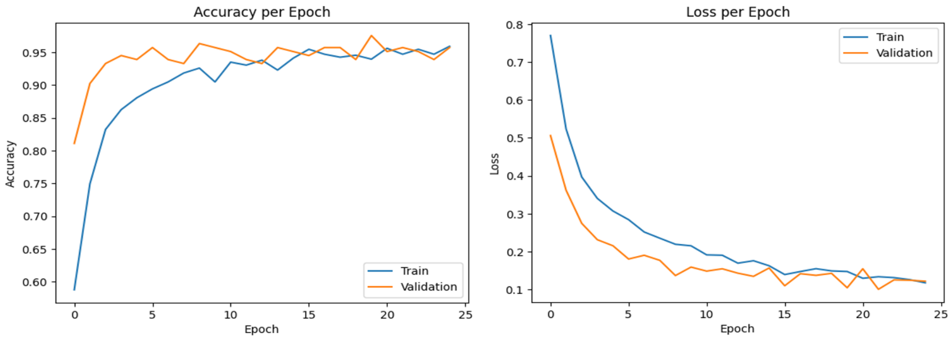

Figure 4 - Training and validation curves of the MobileNetV2 model: on the left – accuracy, on the right – loss.

Performance on the test set

The test set (10% of the total data, about 83 images) was used to evaluate the generalization ability of the model. The main metrics: accuracy – 95.8%, precision – 96.1% (for birds), 95.4% (for drones), recall – 94.7% (for birds), 96.5% (for drones), F1-score – 95.4% (for birds), 95.9% (for drones). Table 2 below shows the metrics by class.

Table 2 - Performance metrics by class on the test set.

Class	Precision	Recall	F1-score	Support
Birds	0.961	0.947	0.954	40
Drones	0.954	0.965	0.959	43
macro avg	0.958	0.956	0.957	83

The confusion matrix is shown below, which visually illustrates the model's errors. According to the matrix, 38 birds were correctly identified, 2 were incorrectly identified (as drones), and 41 drones were correctly identified, 2 were incorrectly identified (as birds) (Figure 5).

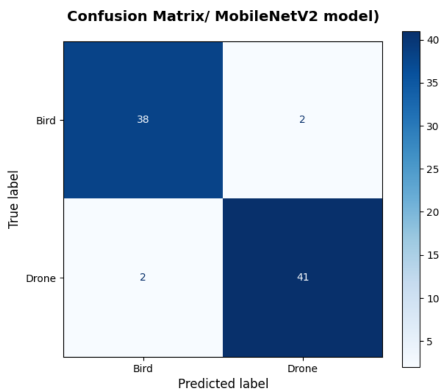

Figure 5 - Confusion matrix result of the MobileNetV2 model.

The practical operation of the model is shown in (Figure 6), where each object in the image is classified and labeled "Bird" or "Drone". The example contains 6 images: Bird (birds in black silhouette), Bird (bird at sunset), Drone (drone and person), Bird (flock of birds in the sky), Drone (flying drone), Bird (lonely bird) .

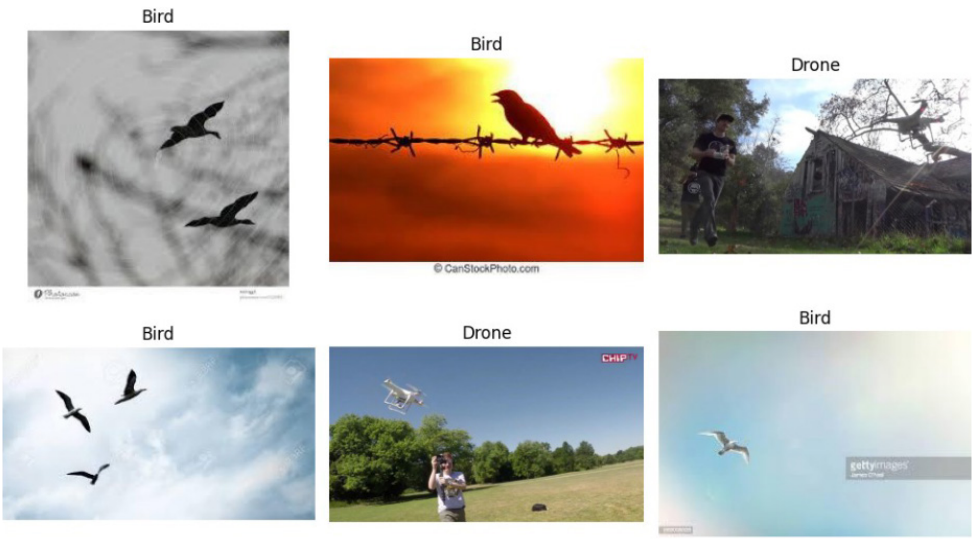

Figure 6 - Classification results of the MobileNetV2 model on sample images

Discussions. In the field of modern airspace control and security, the task of visually distinguishing birds and unmanned aerial vehicles (drones) is of particular importance. This issue is becoming increasingly relevant, especially in practical tasks such as detecting illegal flights, protecting airports and strategic facilities, and conducting environmental monitoring. In this research work, a lightweight convolutional neural network model based on the MobileNetV2 architecture is proposed and experimental analysis is conducted on the Birds vs Drone dataset. The main goal of the study was to develop an efficient classification system that works quickly with high accuracy on devices with limited computing resources.

Experimental results showed that the developed model has high efficiency in distinguishing birds and drones. The model achieved high accuracy on the test set, and the evaluation metrics for each class showed satisfactory values. Confusion matrix analysis revealed a low proportion of misclassifications, which proves that the model has a sufficient level of data generalization ability, regardless of different lighting conditions and background changes. The use of the MobileNetV2 architecture is justified by the small number of parameters and low computational complexity, so it is suitable for implementation in real-time systems. The results obtained are competitive with the results of studies based on more complex architectures such as ResNet and YOLO, which provides a significant advantage for use on resource-constrained platforms.

This work is distinguished by its scientific and practical importance. First, the effectiveness of a lightweight model for distinguishing birds and drones was proven on real data. Second, the use of transfer learning and data augmentation methods allowed us to obtain high results even on small datasets. Third, the proposed approach contributes to solving applied tasks aimed at developing intelligent systems for airspace control.

Conclusion. At the same time, the research work has a number of limitations. The size of the dataset used is relatively small, and the quality of the images and the shooting conditions were not uniform. Since the study was mainly conducted in daylight conditions, night shots or bad weather conditions were not considered separately. The model includes only two classes, and the issues of multi-class classification or distinguishing specific bird species and drone models are beyond the scope of the study. In the future, it is reasonable to continue the study by expanding the dataset, including night and infrared images, and introducing different weather and altitude conditions. In addition, comparing the model with other lightweight architectures, testing it on real-time video streams, deploying it on edge devices, and comprehensively analyzing energy consumption and performance indicators are among the important directions. In general, the developed model based on the MobileNetV2 architecture is an effective, practical, and resource-efficient solution for solving the problem of distinguishing birds from drones. It can be concluded that the research results will serve as a basis for improving safe airspace management systems and developing mechanisms for monitoring the legality of unmanned aerial vehicles.

References

Alqaraleh M., Alzboon M.S., & Al-Batah M.S. (2024) Skywatch: Advanced Machine Learning Techniques for Distinguishing UAVs from Birds in Airspace Security. *Int J Adv Comput Sci Appl [Internet]*, *15*(11). — P. 1065-78. DOI: *10.14569/IJACSA.2024.01511104 (in Eng.)*

Manna A., Upasani N., Jadhav S., Mane R., Chaudhari R., & Chatre V. (2023) Bird image classification using convolutional neural network transfer learning architectures. *International Journal of Advanced Computer Science and Applications*. — *14*(3) p. DOI: *10.14569/IJACSA.2023.0140397 (in Eng.)*

Kondaveeti H.K., Guturu S.S.V., Praveen K.J., & Kumar S.V. (2023, May) A transfer learning approach to bird species recognition using MobileNetV2. In *2023 7th International Conference on Intelligent Computing and Control Systems (ICICCS)*. — P. 787-794). IEEE. DOI**:** *10.1109/ICICCS56967.2023.10142795 (in Eng.)*

Al Dawasari H.J., Bilal M., Moinuddin M., Arshad K., & Assaleh K. (2023) DeepVision: Enhanced drone detection and recognition in visible imagery through deep learning networks. *Sensors*, *23*(21). — 8711 p. *https://doi.org/10.3390/s23218711 (in Eng.)*

Kamil K.H., & Al-Saleh A.H. (2024, December) Drone Detection and Recognition Using Visual Range Based on Deep Convolutional Neural Network. In *International Conference on Artificial Intelligence of Things*. — P. 78-93. Cham: Springer Nature Switzerland. DOIhttps://doi.org/10.1007/978-3-032-07742-4_7 *(in Eng.)*

Ahmad A., Wanto A., & Adnan S.M. (2025) Bird and Drone Image Classification Using ResNet CNN: A Deep Learning Approach for Aerial Surveillance. *Bulletin of Computer Science Research*, *5*(4). — P. 372-381. DOI: *https://doi.org/10.47065/bulletincsr.v5i4.545 (in Eng.)*

Nagamani P., Reddy K.P.K., Pujitha K., Sri P.K., & Narang K. (2025) Sky Guard: A Vision

Based Drone Vs. Bird Detection and Alert System Using Deep Learning. In *Algorithms in Advanced Artificial Intelligence*. — P. 177-183. CRC Press. *https://doi.org/10.1201/9781003641537 (in Eng.)*

Başaran B., & Emekci H. (2025, September) Classification of Flying Objects with Computer Vision and Deep Learning Integrated System. In *2025 10th International Conference on Computer Science and Engineering (UBMK)*. — P. 969-974. IEEE. doi: 10.1109/UBMK67458.2025.11206844. *(in Eng.)*

Linero-Ramos R., Parra-Rodríguez C., & Gongora M. (2025) SVMobileNetV2: A Hybrid and Hierarchical CNN-SVM Network Architecture Utilising UAV-Based Multispectral Images and IoT Nodes for the Precise Classification of Crop Diseases. *AgriEngineering*, *7*(10). — 341 p. *https://doi.org/10.3390/agriengineering7100341 (in Eng.)*

Rawat D., Khetarpal D., Khetarpal I., Vats S., & Sharma V. (2025, May) Wide-Angle Threat Detection: Fisheye Imaging and Machine Learning for Enhanced Drone and Bird Surveillance. In *2025 International Conference on Networks and Cryptology (NETCRYPT)*. — P. 1945-1950. IEEE. doi: 10.1109/NETCRYPT65877.2025.11102753. *(in Eng.)*

Liang H., Zhang X., Kong J., Zhao Z., & Ma K. (2024) SMB-YOLOv5: a lightweight airport flying bird detection algorithm based on deep neural networks. *IEEE Access*, *12*. — P. 84878-84892. doi: 10.1109/ACCESS.2024.3415385. *(in Eng.)*

Irungu J., Smith H., Cruz J., Kacem T., & Girma A. (2023, December) Unmanned Aerial Vehicles Detection Using CNN Transfer Learning. In *International Conference on Security and Information Technologies with AI, Internet Computing and Big-data Applications*. — P. 345-356). Singapore: Springer Nature Singapore. DOIhttps://doi.org/10.1007/978-981-97-7786-0_28 *(in Eng.)*

Shek S.C.K. (2025) Artificial Intelligence Based Image Recognition Using Limited-Resource Hardware for an Aerial Drone Application. DOI: *10.17034/ecb939fd-5749-44d0-98bf-9e87dd494ded (in Eng.)*

Mary A.V.A., Anusha N., Selvan M.P., Rajalakshmi R., Jancy S., & Grace L.J. (2024, November) Enforcement of CNN Model in Drone Detection System. In *2024 International Conference on Recent Advances in Science and Engineering Technology (ICRASET)*. — P. 1-6. IEEE. doi: 10.1109/ICRASET63057.2024.10895675. *(in Eng.)*

Allmamun M., Akter F., Talukdar M.B.U., Chakraborty S., & Uddin J. (2024) Drone Detection and Tracking using Deep Convolutional Neural Networks from Real-time CCTV Footage. *IEIE Transactions on Smart Processing & Computing*, *13*(4). — P. 313-321. DOI: 10.5573/IEIESPC.2024.13.4.313 *(in Eng.)*

Puduru V.K., Pardhasaradhi B., Koorapati S., & Cenkeramaddi L.R. (2025, March) Lightweight Deep Learning Model for Airborne Object Classification. In *2025 IEEE 14th International Conference on Communication Systems and Network Technologies (CSNT).* — P. 230-234. IEEE. doi: 10.1109/CSNT64827.2025.10968603. *(in Eng.)*

Sarkar S., & Kelley R. (2023, April) A UAV and deep transfer learning based environmental monitoring: Application to native and invasive species classification in southern regions of the USA. In *2023 IEEE conference on technologies for sustainability (SusTech)*. — P. 6-11. IEEE. doi: 10.1109/SusTech57309.2023.10129545. *(in Eng.)*

Publication Ethics and Publication Malpractice in the journals of the Central Asian Academic Research Center LLP

For information on Ethics in publishing and Ethical guidelines for journal publication see http://www.elsevier.com/publishingethics and http://www.elsevier.com/journal-authors/ethics.

Submission of an article to the journals of the Central Asian Academic Research Center LLP implies that the described work has not been published previously (except in the form of an abstract or as part of a published lecture or academic thesis or as an electronic preprint, see http://www.elsevier.com/postingpolicy), that it is not under consideration for publication elsewhere, that its publication is approved by all authors and tacitly or explicitly by the responsible authorities where the work was carried out, and that, if accepted, it will not be published elsewhere in the same form, in English or in any other language, including electronically without the written consent of the copyright-holder. In particular, translations into English of papers already published in another language are not accepted.

No other forms of scientific misconduct are allowed, such as plagiarism, falsification, fraudulent data, incorrect interpretation of other works, incorrect citations, etc. The Central Asian Academic Research Center LLP follows the Code of Conduct of the Committee on Publication Ethics (COPE), and follows the COPE Flowcharts for Resolving Cases of Suspected Misconduct (http://publicationethics.org/files/u2/New_Code.pdf). To verify originality, your article may be checked by the Cross Check originality detection service http://www.elsevier.com/editors/plagdetect.

The authors are obliged to participate in peer review process and be ready to provide corrections, clarifications, retractions and apologies when needed. All authors of a paper should have significantly contributed to the research.

The reviewers should provide objective judgments and should point out relevant published works which are not yet cited. Reviewed articles should be treated confidentially. The reviewers will be chosen in such a way that there is no conflict of interests with respect to the research, the authors and/or the research funders.

The editors have complete responsibility and authority to reject or accept a paper, and they will only accept a paper when reasonably certain. They will preserve anonymity of reviewers and promote publication of corrections, clarifications, retractions and apologies when needed. The acceptance of a paper automatically implies the copyright transfer to the Central Asian Academic Research Center LLP.

The Editorial Board of the Central Asian Academic Research Center LLP will monitor and safeguard publishing ethics.

Requirements for articles design for publication in the journal are available on the websites:
www:nauka-nanrk.kz
http://physics-mathematics.kz/index.php/en/archive
ISSN2518-1726 (Online),
ISSN 1991-346X (Print)

Managing Editor: *A.Shormakova*
Editors: *D.S. Alenov, T. Apendiev*
Computer layout: *G.D. Zhadyranova*

Signed for print: June 15, 2026
Format: 70×90 1/16. 26.5 printed sheets. Order No. 2.

«Central Asian Academic Research Center» LLP
Almaty, Shevchenko Street, 28