

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

Chief Editor:

MUTANOV Galimkair Mutanovich, doctor of technical sciences, professor, academician of NAS RK, (Almaty, Kazakhstan), <https://www.scopus.com/authid/detail.uri?authorId=6506682964>, <https://www.webofscience.com/wos/author/record/1423665>

EDITORIAL BOARD:

KALIMOLDAYEV Maksat Nuradilovich, (Deputy Editor-in-Chief), Doctor of Physical and Mathematical Sciences, Professor, Academician of NAS RK, Advisor to the General Director of the Institute of Information and Computing Technologies of the CS MES RK, Head of the Laboratory (Almaty, Kazakhstan), <https://www.scopus.com/authid/detail.uri?authorId=56153126500>, <https://www.webofscience.com/wos/author/record/2428551>

MAMYRBAEV Orken Zhumazhanovich, (Academic Secretary), PhD in Information Systems, Deputy Director for Science of the Institute of Information and Computing Technologies CS MES RK (Almaty, Kazakhstan), <https://www.scopus.com/authid/detail.uri?authorId=55967630400>, <https://www.webofscience.com/wos/author/record/1774027>

BAIGUNCHEKOV Zhumadil Zhanabaevich, Doctor of Technical Sciences, Professor, Academician of NAS RK, Institute of Cybernetics and Information Technologies, Department of Applied Mechanics and Engineering Graphics, Satbayev University (Almaty, Kazakhstan), <https://www.scopus.com/authid/detail.uri?authorId=6506823633>, <https://www.webofscience.com/wos/author/record/1923423>

WOICIK Waldemar, Doctor of Technical Sciences (Phys.-Math.), Professor of the Lublin University of Technology (Lublin, Poland), <https://www.scopus.com/authid/detail.uri?authorId=7005121594>, <https://www.webofscience.com/wos/author/record/678586>

SMOLARJ Andrej, Associate Professor Faculty of Electronics, Lublin polytechnic university (Lublin, Poland), <https://www.scopus.com/authid/detail.uri?authorId=56249263000>, <https://www.webofscience.com/wos/author/record/1268523>

KEILAN Alimkhan, Doctor of Technical Sciences, Professor (Doctor of science (Japan)), chief researcher of Institute of Information and Computational Technologies CS MES RK (Almaty, Kazakhstan), <https://www.scopus.com/authid/detail.uri?authorId=8701101900>, <https://www.webofscience.com/wos/author/record/1436451>

KHAIROVA Nina, Doctor of Technical Sciences, Professor, Chief Researcher of the Institute of Information and Computational Technologies CS MES RK (Almaty, Kazakhstan), <https://www.scopus.com/authid/detail.uri?authorId=37461441200>, <https://www.webofscience.com/wos/author/record/1768515>

OTMAN Mohamed, PhD, Professor of Computer Science Department of Communication Technology and Networks, Putra University Malaysia (Selangor, Malaysia), <https://www.scopus.com/authid/detail.uri?authorId=56036884700>, <https://www.webofscience.com/wos/author/record/747649>

NYSANBAYEVA Saule Yerkebulanovna, Doctor of Technical Sciences, Associate Professor, Senior Researcher of the Institute of Information and Computing Technologies CS MES RK (Almaty, Kazakhstan), <https://www.scopus.com/authid/detail.uri?authorId=55453992600>, <https://www.webofscience.com/wos/author/record/3802041>

USATOVA Olga Alexandrovna, PhD, Associate Professor, Chief Scientific Secretary of the Institute of Information and Computing Technologies of the National Academy of Sciences of the Republic of Kazakhstan (Almaty, Kazakhstan), <https://www.scopus.com/authid/detail.uri?authorId=57204581062>, <https://www.webofscience.com/wos/author/record/JCO-3058-2023>

KAPALOVA Nursulu Aldazharovna, Candidate of Technical Sciences, Head of the Laboratory cybersecurity, Institute of Information and Computing Technologies CS MES RK (Almaty, Kazakhstan), <https://www.scopus.com/authid/detail.uri?authorId=57191242124>,

KOVALYOV Alexander Mikhailovich, Doctor of Physical and Mathematical Sciences, Academician of the National Academy of Sciences of Ukraine, Institute of Applied Mathematics and Mechanics (Donetsk, Ukraine), <https://www.scopus.com/authid/detail.uri?authorId=7202799321>, <https://www.webofscience.com/wos/author/record/38481396>

MIKHALEVICH Alexander Alexandrovich, Doctor of Technical Sciences, Professor, Academician of the National Academy of Sciences of Belarus (Minsk, Belarus), <https://www.scopus.com/authid/detail.uri?authorId=7004159952>, <https://www.webofscience.com/wos/author/record/46249977>

TIGHINEANU Ion Mihailovich, Doctor of Physical and Mathematical Sciences, Academician, President of the Academy of Sciences of Moldova, Technical University of Moldova (Chisinau, Moldova), <https://www.scopus.com/authid/detail.uri?authorId=7006315935>, <https://www.webofscience.com/wos/author/record/524462>

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/>

© «Central Asian Academic Research Center» LLP, 2026

БАС РЕДАКТОР:

МУТАНОВ Ғалымқайыр Мұтанұлы, техника ғылымдарының докторы, профессор, ҚР ҰҒА академигі, (Алматы, Қазақстан), <https://www.scopus.com/authid/detail.uri?authorId=6506682964>, <https://www.webofscience.com/wos/author/record/1423665>

РЕДАКЦИЯ АЛҚАСЫ:

КАЛИМОЛДАЕВ Мақсат Нұрәділұлы, (бас редактордың орынбасары), физика-математика ғылымдарының докторы, профессор, ҚР ҰҒА академигі, ҚР ҒЖБМ ҒК «Ақпараттық және есептеу технологиялары институты» бас директорының кеңесшісі, зертхана меңгерушісі (Алматы, Қазақстан), <https://www.scopus.com/authid/detail.uri?authorId=56153126500>, <https://www.webofscience.com/wos/author/record/2428551>

МАМЫРБАЕВ Өркен Жұмажанұлы (ғалым хатшы), Ақпараттық жүйелер саласындағы техника ғылымдарының (PhD) докторы, ҚР ҒЖБМ ҒК «Ақпараттық және есептеу технологиялары институты» директорының ғылым жөніндегі орынбасары (Алматы, Қазақстан), <https://www.scopus.com/authid/detail.uri?authorId=55967630400>, <https://www.webofscience.com/wos/author/record/1774027>

БАЙГУНЧЕКОВ Жұмаділ Жаңабайұлы, техника ғылымдарының докторы, профессор, ҚР ҰҒА академигі, Кибернетика және ақпараттық технологиялар институты, Қолданбалы механика және инженерлік графика кафедрасы, Сәтбаев университеті (Алматы, Қазақстан), <https://www.scopus.com/authid/detail.uri?authorId=6506823633>, <https://www.webofscience.com/wos/author/record/1923423>

ВОЙЧИК Вальдемар, техника ғылымдарының докторы (физ-мат), Люблин технологиялық университетінің профессоры (Люблин, Польша), <https://www.scopus.com/authid/detail.uri?authorId=7005121594>, <https://www.webofscience.com/wos/author/record/678586>

СМОЛАРЖ Анджей, Люблин политехникалық университетінің электроника факультетінің доценті (Люблин, Польша), <https://www.scopus.com/authid/detail.uri?authorId=56249263000>, <https://www.webofscience.com/wos/author/record/1268523>

КЕЙЛАН Әлімхан, техника ғылымдарының докторы, профессор (ғылым докторы (Жапония)), ҚР ҒЖБМ ҒК «Ақпараттық және есептеу технологиялары институтының» бас ғылыми қызметкері (Алматы, Қазақстан), <https://www.scopus.com/authid/detail.uri?authorId=8701101900>, <https://www.webofscience.com/wos/author/record/1436451>

ХАЙРОВА Нина, техника ғылымдарының докторы, профессор, ҚР ҒЖБМ ҒК «Ақпараттық және есептеу технологиялары институтының» бас ғылыми қызметкері (Алматы, Қазақстан), <https://www.scopus.com/authid/detail.uri?authorId=37461441200>, <https://www.webofscience.com/wos/author/record/1768515>

ОТМАН Мохаммед, PhD, Информатика, Коммуникациялық технологиялар және желілер кафедрасының профессоры, Путра университеті Малайзия (Селангор, Малайзия), <https://www.scopus.com/authid/detail.uri?authorId=56036884700>, <https://www.webofscience.com/wos/author/record/747649>

НЫСАНБАЕВА Сауле Еркебұланқызы, техника ғылымдарының докторы, доцент, ҚР ҒЖБМ ҒК «Ақпараттық және есептеу технологиялары институтының» аға ғылыми қызметкері (Алматы, Қазақстан), <https://www.scopus.com/authid/detail.uri?authorId=55453992600>, <https://www.webofscience.com/wos/author/record/3802041>

УСАТОВА Ольга Александровна, PhD, қауымдастырылған профессор, ҚР ҒЖБМ "Ақпараттық және есептеу технологиялары институтының" бас ғалым хатшысы (Алматы, Қазақстан), <https://www.scopus.com/authid/detail.uri?authorId=57204581062>, <https://www.webofscience.com/wos/author/record/JCO-3058-2023>

КАПАЛОВА Нұрсұлу Алдажарқызы, техника ғылымдарының кандидаты, ҚР ҒЖБМ ҒК «Ақпараттық және есептеу технологиялары институты», Киберқауіпсіздік зертханасының меңгерушісі (Алматы, Қазақстан), <https://www.scopus.com/authid/detail.uri?authorId=57191242124>,

КОВАЛЕВ Александр Михайлович, физика-математика ғылымдарының докторы, Украина Ұлттық Ғылым академиясының академигі, Қолданбалы математика және механика институты (Донецк, Украина), <https://www.scopus.com/authid/detail.uri?authorId=7202799321>, <https://www.webofscience.com/wos/author/record/38481396>

МИХАЛЕВИЧ Александр Александрович, техника ғылымдарының докторы, профессор, Беларусь Ұлттық Ғылым академиясының академигі (Минск, Беларусь), <https://www.scopus.com/authid/detail.uri?authorId=7004159952>, <https://www.webofscience.com/wos/author/record/46249977>

ТИГИНЯНУ Ион Михайлович, физика-математика ғылымдарының докторы, академик, Молдова Ғылым Академиясының президенті, Молдова техникалық университеті (Кишинев, Молдова), <https://www.scopus.com/authid/detail.uri?authorId=7006315935>, <https://www.webofscience.com/wos/author/record/524462>

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/>

© «Орталық Азия академиялық ғылыми орталығы» ЖШС, 2026

Главный редактор:

МУТАНОВ Галимканр Мутанович, доктор технических наук, профессор, академик НАН РК, (Алматы, Казахстан), <https://www.scopus.com/author/detail.uri?authorId=6506682964>, <https://www.webofscience.com/wos/author/record/1423665>

Редакционная коллегия:

КАЛИМОЛДАЕВ Максат Нурадилович, (заместитель главного редактора), доктор физико-математических наук, профессор, академик НАН РК, советник генерального директора «Института информационных и вычислительных технологий» КН МНВО РК, заведующий лабораторией (Алматы, Казахстан), <https://www.scopus.com/author/detail.uri?authorId=56153126500>, <https://www.webofscience.com/wos/author/record/2428551>

МАМЫРБАЕВ Оркен Жумажанович, (ученый секретарь), доктор философии (PhD) по специальности «Информационные системы», заместитель директора по науке РГП «Институт информационных и вычислительных технологий» Комитета науки МНВО РК (Алматы, Казахстан), <https://www.scopus.com/author/detail.uri?authorId=55967630400>, <https://www.webofscience.com/wos/author/record/1774027>

БАЙГУНЧЕКОВ Жумадил Жанабаевич, доктор технических наук, профессор, академик НАН РК, Институт кибернетики и информационных технологий, кафедра прикладной механики и инженерной графики, Университет Сагпаева (Алматы, Казахстан), <https://www.scopus.com/author/detail.uri?authorId=6506823633>, <https://www.webofscience.com/wos/author/record/1923423>

ВОЙЧИК Вальдемар, доктор технических наук (физ.-мат.), профессор Люблинского технологического университета (Люблин, Польша), <https://www.scopus.com/author/detail.uri?authorId=7005121594>, <https://www.webofscience.com/wos/author/record/678586>

СМОЛАРЖ Анджей, доцент факультета электроники Люблинского политехнического университета (Люблин, Польша), <https://www.scopus.com/author/detail.uri?authorId=56249263000>, <https://www.webofscience.com/wos/author/record/1268523>

КЕЙЛАН Алимхан, доктор технических наук, профессор (Doctor of science (Japan)), главный научный сотрудник РГП «Института информационных и вычислительных технологий» КН МНВО РК (Алматы, Казахстан), <https://www.scopus.com/author/detail.uri?authorId=8701101900>, <https://www.webofscience.com/wos/author/record/1436451>

ХАЙРОВА Нина, доктор технических наук, профессор, главный научный сотрудник РГП «Института информационных и вычислительных технологий» КН МНВО РК (Алматы, Казахстан), <https://www.scopus.com/author/detail.uri?authorId=37461441200>, <https://www.webofscience.com/wos/author/record/1768515>

ОТМАН Мохамед, доктор философии, профессор компьютерных наук, Департамент коммуникационных технологий и сетей, Университет Путра Малайзия (Селангор, Малайзия), <https://www.scopus.com/author/detail.uri?authorId=56036884700>, <https://www.webofscience.com/wos/author/record/747649>

НЫСАНБАЕВА Сауле Еркебулановна, доктор технических наук, доцент, старший научный сотрудник РГП «Института информационных и вычислительных технологий» КН МНВО РК (Алматы, Казахстан), <https://www.scopus.com/author/detail.uri?authorId=55453992600>, <https://www.webofscience.com/wos/author/record/3802041>

УСАТОВА Ольга Александровна, PhD, ассоциированный профессор, Главный ученый секретарь «Института информационных и вычислительных технологий» КН МНВО РК (Алматы, Казахстан), <https://www.scopus.com/author/detail.uri?authorId=57204581062>, <https://www.webofscience.com/wos/author/record/JCO-3058-2023>

КАПАЛОВА Нурсулу Алдажаровна, кандидат технических наук, заведующий лабораторией кибербезопасности РГП «Института информационных и вычислительных технологий» КН МНВО РК (Алматы, Казахстан), <https://www.scopus.com/author/detail.uri?authorId=57191242124>,

КОВАЛЕВ Александр Михайлович, доктор физико-математических наук, академик НАН Украины, Институт прикладной математики и механики (Донецк, Украина), <https://www.scopus.com/author/detail.uri?authorId=7202799321>, <https://www.webofscience.com/wos/author/record/38481396>

МИХАЛЕВИЧ Александр Александрович, доктор технических наук, профессор, академик НАН Беларуси (Минск, Беларусь), <https://www.scopus.com/author/detail.uri?authorId=7004159952>, <https://www.webofscience.com/wos/author/record/46249977>

ТИГИНЯНУ Ион Михайлович, доктор физико-математических наук, академик, президент Академии наук Молдовы, Технический университет Молдовы (Кишинев, Молдова), <https://www.scopus.com/author/detail.uri?authorId=7006315935>, <https://www.webofscience.com/wos/author/record/524462>

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 № **KZ77VRY00121154**. Дата выдачи **05.06.2025**

Тематическая направленность: *информационно-коммуникационные технологии.*

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

Периодичность: *4 раза в год.*

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

© ТОО «Центрально-азиатский академический научный центр», 2026

CONTENTS

COMPUTER SCIENCE

Abduraimova B.K., Toleukhan A.B., Sapakova S.Z., Abisheva A.A. Development of early cyberattack detection method using CNN-LSTM for IoT.....	11
Aben A.B., Kazbekova G.N., Baimakhanova A.S., Amanzholova A.B. Classification of birds and drones in the sky using MobileNetV2 model.....	30
Akbarov D., Sembayev T. Quality-aware pose–hand keypoint extraction pipeline for skeleton-based sign language recognition.....	44
Algazy K., Alimzhan Y., Sakan K., Nyssanbayeva S. Lattice-based vector commitments for Verkle trees.....	67
Asylkhan N., Baidrakhmanova M.G. Principles and models of spatial organization of buildings for crop production considering technological and climatic factors.....	87
Basheyeva Zh., Tokesh A., Bekish U., Abdoldinova G. Artificial intelligence for academic project management: a bibliometric analysis and systematic review.....	105
Bekmanova G., Kantureyeva M., Omarbekova A., Zakirova A., Issainova A. Integrating artificial intelligence to evaluate emotions in the learning environment.....	125
Dzhusupbekova G.T., Jangassiyev R.M. Gemini AI integration based on .NET MAUI for education: hybrid architecture and empirical load testing.....	146
Doszhan N.S., Sultanbekova L.Ye., Zhumagali S.Zh., Konysbayev E.K. Modeling and parameter calculation of an emergency response system based on LoRaWAN technology in the high-altitude conditions of the Zailiysky Alatau.....	166
Zhumakhanova A., Kudabayeva R., Akanova K., Myrkanova A. Entropy-normalized multidimensional model for user activity segmentation in Reddit...	180
Karabaliyev Y., Kolesnikova K., Khlevnaya Y. HybridKazASR: a hybrid automatic speech recognition system combining multi-model rover fusion and morpheme-aware language modeling for Kazakh.....	198
Kerimkhulle S.E., Adalbek A., Baizakov N.A., Shodorova N.N. Piecewise logistic and fuzzy modeling of Kazakhstan's GDP dynamics (1990–2024)....	212
Kulakayeva A., Ashurov A., Aitmagambetov A., Ongenbayeva Zh. Development of mathematical models and criteria for the admissibility of orbital maneuvers of spacecraft.....	228

Kulatay A.A., Zhaisanova D.S., Daurenbayeva N.A., Mamanova S.Y., Tolegen M.
 Machine learning for personalized learning in gamified edtech platforms:
 Aqyl Battle case.....248

Mamyrbayev O., Kurmetkan T.
 Enhanced sentiment analysis of e-commerce product reviews using
 Luong attention-based Bi-LSTM.....263

Marassulov U.A., Kazbekova G.
 TF-IDF-based fake news detection in Kazakh and Russian.....286

Omar A.B., Mussiraliyeva Sh.Zh.
 Federated learning: models based on transformer architecture.....302

Rakhimova D., Duisenbekkyzy Zh., Karibayeva A., Eşref A., Ilessova B.
 Improving the voice recognition system for children in Kazakh through additional
 training (fine-tuning).....317

Sarsembayev M, Urmashiev B.
 Optimization of the calculation of kinetic equations of combustion processes on GPU
 using global memory and shared memory.....335

Symagulov A., Smurygin V., Belousov A., Karypov A., Yunicheva N.R.
 Improving the accuracy of crop and weed detection using UAVs in soya fields
 through image segmentation.....347

Tashenova Zh., Gabdullin A.R., Abdugulova Zh., Amanzholova Sh., Santeyeva S.
 Security evaluation of WPA3 wireless networks under deauthentication
 attack scenarios.....368

**Tursunbayeva G.U., Satybalдина D.Zh., Tleuberdin S.T., Tashatov N.N.,
 Egamberdiyev E.E.**
 Anomaly detection in UAV telemetry systems based on simulation modeling.....391

Tursynova N., Yerimbetova A., Amangeldy N., Zhumabayeva A., Daiyrbayeva E.
 Comparative analysis of multilingual transformer models for Kazakh-to-gloss
 translation.....414

Shangpeng Lei, Balakayeva G.
 Dual-branch physical information neural networks for data center airflow velocity
 and thermal modeling.....433

Shynzhigit B.B., Balabekova M.O., Amangeldy T.T., Malik G.J., Balgimbekova U.B.
 Automatic brick defects detection by using a CNN-based deep learning model.....449

МАЗМҰНЫ

КОМПЬЮТЕРЛІК ҒЫЛЫМДАР

Абдураимова Б.К., Төлеухан Ә.Б., Сапакова С.З., Абишева А.А. Кибершабулдарды ерте анықтау әдісін CNN-LSTM негізінде дамыту (IoT үшін).....	11
Абен А.Б., Қазбекова Г.Н., Баймаханова А.С., Аманжолова Ә.Б. MobileNetV2 моделімен аспандағы құстар мен дрондарды классификациялау.....	30
Ақбаров Д.Р., Сембаев Т.М. Ым тілін тануға арналған дене қалпы мен қолдың негізгі нүктелерін сапаны бақылаумен анықтау әдісі.....	44
Алғазы К.Т., Әлімжан Е.Ж., Сақан Қ.С., Нысанбаева С.Е. Verkle ағаштарына арналған торлық векторлық міндеттемелер.....	67
Асылхан Н., Байдрахманова М.Г. Технологиялық және климаттық факторларды ескере отырып, өсімдік шаруашылығы ғимараттарының кеңістік ұйымдастыру қағидалары мен модельдері.....	87
Башеева Ж., Төкеш Ә., Бекіш Ұ., Абдолдинова Г. Академиялық жобаларды басқарудағы жасанды интеллект: библиометриялық талдау және жүйелі шолу.....	105
Бекманова Г.Т., Кантурсева М.А., Омарбекова А.С., Закирова А.Б., Исайнова А.Н. Оқу ортасындағы эмоцияларды бағалау үшін жасанды интеллектті біріктіру.....	125
Джусупбекова Г.Т., Жангасиев Р.М. Білім беруге арналған .NET MAUI негізіндегі Gemini AI интеграциясы: гибриді архитектуралық және эмпирикалық жүктемелік тестілеу.....	146
Досжан Н.С., Султанбекова Л.Е., Жумағали С.Ж., Қонысбаев Е.К. Іле Алатауының биік таулы жағдайында LORAWAN технологиясы негізіндегі жедел әрекет ету жүйесінің параметрлерін модельдеу және есептеу.....	166
Жумаханова А., Қудабаева Р., Ақанова К., Мырқанова А. REDDIT-те пайдаланушы әрекетін сегменттеуге арналған энтропия-нормалданған көп өлшемді модель.....	180
Қарабаев Е., Колесникова К., Хлевная Ю. HybridKazASR: Rover көпмодельді біріктіру және морфемеге негізделген тілдік модельдеуді пайдаланатын қазақ тілін автоматты тану гибриді жүйесі.....	198
Керімқұл С.Е., Адалбек А., Байзақов Н.А., Шодорова Н.Н. Қазақстан ЖІӨ динамикасын кезеңдік (Piecewise) логистикалық және бұлдыр модельдеу (1990–2024).....	212

Кулакаева А.Е., Ашуров А.Е., Айтмағамбетов А.З., Онгенбаева Ж.Ж. Ғарыш аппараттарының орбиталық маневрлерінің математикалық модельдері мен рұқсат критерийлерін әзірлеу.....	228
Құлатай А.А., Жайсанова Д.С., Дауренбаева Н.А., Маманова С.Е., Төлеген М. Геймификацияланған edtech платформаларда оқытуды жекелендіруге арналған машиналық.....	248
Мамырбаев Ө.Ж., Құрметқан Т. Луонг назар механизміне негізделген BI-LSTM көмегімен электрондық коммерция өнімдеріне жазылған пікірлерге жетілдірілген сентименттік талдау жасау.....	263
Марасулов У.А., Казбекова Г. Қазақ және орыс тілдеріндегі жалған жаңалықтарды TF-IDF арқылы анықтау.....	286
Омар А.Б., Мусиралиева Ш.Ж. Федеративті оқыту: трансформер архитектурасына негізделген модельдер.....	302
Рахимова Д., Дүйсенбекқызы Ж., Кәрібаева А., Ешref А., Ілесова Б. Қазақ тіліндегі балалар дауысын тану жүйесін қосымша оқыту (Fine-Tuning) арқылы жетілдіру.....	317
Сарсембаев М., Урмашев Б. Global memory және shared memory қолдану арқылы GPU-да жану процестерінің кинетикалық теңдеулерін есептеуді оңтайландыру.....	335
Сымагулов А., Смурыгин В., Белоусов А., Карыпов А., Юничева Н.Р. Соя алқаптарында ҰҰА көмегімен мәдени және арамшөп өсімдіктерін детекттеу сапасын кескіндерді сегменттеу арқылы арттыру.....	347
Ташенова Ж.М., Габдуллин А.Р., Абдугулова Ж.К., Аманжолова Ш.А., Сантеева С.Ә. Деатентификациялау шабуылы сценарийлеріндегі WPA3 сымсыз желілерінің қауіпсіздігін бағалау.....	368
Турсунбаева Г., Сатыбалдина Д., Глеубердин С., Ташатов Н., Эгамбердиев Э. Симуляциялық модельдеу негізінде ұшқышсыз ұшу аппараттарының телеметриялық жүйелеріндегі аномалияларды анықтау.....	391
Турсынова Н., Еримбетова А., Амангелді Н., Жумабаева А., Дайырбаева Э. Қазақ тілінен глосска аудару үшін көптілді трансформерлік модельдердің салыстырмалы талдауы.....	414
Шанпэн Лей, Балакаева Г. Деректер орталығының ауа ағынының жылдамдығына және термиялық модельдеуге арналған екі тармақты физикалық ақпараттық нейрондық желілер.....	433
Шынжігіт Ш.Б., Балабекова М.О., Амангелді Т.Т., Мәлік Г.Ж., Балгимбекова У.Б. Кіріпші ақауларын автоматты анықтауда snn негізіндегі терең оқыту моделін пайдалану.....	449

СОДЕРЖАНИЕ

КОМПЬЮТЕРНЫЕ НАУКИ

Абдураимова Б.К., Толеухан А.Б., Сапакова С.З., Абишева А.А. Разработка метода раннего обнаружения кибератак на основе CNN-LSTM для IoT.....	11
Абен А.Б., Казбекова Г.Н., Баймаханова А.С., Аманжолова А.Б. Классификация птиц и дронов в небе с использованием модели MobileNetV2.....	30
Акбаров Д.Р., Сембаев Т.М. Метод получения ключевых точек позы и кистей с контролем качества для распознавания жестового языка.....	44
Алгазы К.Т., Алимжан Е.Ж., Сакан К.С., Нысанбаева С.Е. Решеточные векторные обязательства для Verkle-деревьев.....	67
Асылхан Н., Байдрахманова М.Г. Принципы и модели пространственной организации зданий для растениеводства с учетом технологических и климатических факторов.....	87
Башеева Ж., Токеш А., Бекиш У., Абдолдинова Г. Искусственный интеллект в управлении академическими проектами: библиометрический анализ и систематический обзор.....	105
Бекманова Г.Т., Кантуреева М.А., Омарбекова А.С., Закирова А.Б., Исайнова А.Н. Интеграция искусственного интеллекта для оценки эмоций в учебной среде.....	125
Джусупбекова Г.Т., Джангасиев Р.М. Интеграция Gemini AI на базе .NET MAUI для образования: гибридная архитектура и эмпирическое нагрузочное тестирование.....	146
Досжан Н.С., Султанбекова Л.Е., Жумагали С.Ж., Коньсбаев Е.К. Моделирование и расчет параметров системы экстренного реагирования на базе технологии LoRaWAN в условиях высокогорья Заилийского Алатау.....	166
Жумаханова А., Кудабаева Р., Аканова К., Мырканова А. Энтропийно-нормализованная многомерная модель для сегментации активности пользователей в Reddit.....	180
Карабалиев Е., Колесникова К., Хлевна Ю. HybridKazASR: гибридная система автоматического распознавания казахской речи на основе многомодельного объединения ROVER и морфемно-ориентированного языкового моделирования.....	198
Керимкулов С.Е., Адалбек А., Байзаков Н.А., Шодорова Н.Н. Кусочно-логистическое и нечеткое моделирование динамики ВВП Казахстана (1990–2024).....	212
Кулакаева А.Е., Ашуров А.Е., Айтмагамбетов А.З., Онгенбаева Ж.Ж. Разработка математических моделей и критериев допустимости орбитальных маневров космических аппаратов.....	228

Кулатай А.А., Жайсанова Д.С., Дауренбаева Н.А., Маманова С.Е., Толеген М. Машинное обучение для персонализации обучения на геймифицированных EdTech-платформах: кейс Aqyl Battle.....	248
Мамырбаев О., Курметкан Т. Усовершенствованный анализ тональности отзывов о товарах электронной коммерции с использованием Bi-LSTM на основе механизма внимания Луонга.....	263
Марасулов У.А., Казбекова Г. Выявление ложных новостей на казахском и русском языках TF-IDF-моделями.....	286
Омар А.Б., Мусиралиева Ш.Ж. Федеративное обучение: модели на основе архитектуры трансформеров.....	302
Рахимова Д., Дуйсенбеккызы Ж., Карибаева А., Еҫref А., Илесова Б. Совершенствование системы распознавания голоса детей на казахском языке путем дополнительного обучения (fine-tuning).....	317
Сарсембаев М., Урмашев Б. Оптимизация расчета кинетических уравнений процессов горения на GPU с использованием global memory и shared memory.....	335
Сымагулов А., Смургин В., Белоусов А., Карыпов А., Юничева Н.Р. Улучшение качества детектирования культурных и сорных растений с помощью БПЛА на полях сои с применением сегментации изображений.....	347
Ташенова Ж.М., Габдуллин А.Р., Абдугулова Ж.К., Аманжолова Ш.А., Сантеева С.А. Оценка безопасности беспроводных сетей WPA3 в условиях атаки с деаутентификацией.....	368
Турсунбаева Г., Сатыбалдина Д., Тлеубердин С., Ташатов Н., Эгамбердиев Э. Обнаружение аномалий в телеметрических системах БПЛА на основе симуляционного моделирования.....	391
Турсынова Н., Еримбетова А., Амангелді Н., Жумабаева А., Дайырбаева Э. Сравнительный анализ многоязычных трансформерных моделей для перевода с казахского языка на глоссированное представление.....	414
Шанпэн Лэй, Балакаева Г. Двухветвевые физически информированные нейронные сети для моделирования воздушных потоков и тепловых условий в центрах обработки данных.....	433
Шынжыгит Ш.Б., Балабекова М.О., Амангелды Т.Т., Малик Г.Ж., Балгимбекова У.Б. Использование модели глубокого обучения на основе CNN для автоматического обнаружения дефектов кирпичной кладки.....	449

ACADEMIC SCIENTIFIC JOURNAL OF COMPUTER SCIENCE
ISSN 1991-346X
Volume 2.
Number 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 (Lineró-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 ($\pm 25^\circ$), scaling (0.85–1.15), horizontal flip, random change in brightness and contrast ($\pm 20\%$), 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 \rightarrow global average pooling \rightarrow 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).

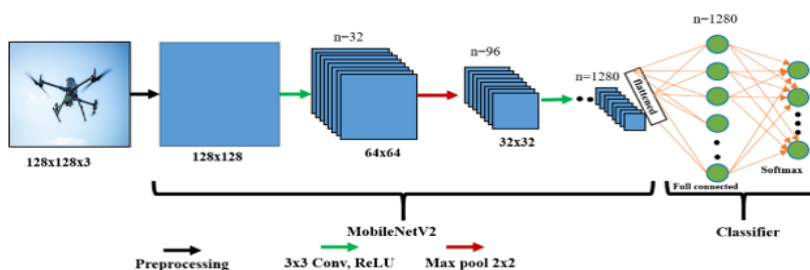


Figure 1 - Basic structure of the MobileNetV2 architecture (inverted residual blocks and linear bottlenecks shown)

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:

$$\text{FLOPs} \approx D_k^2 \times M \times D_f^2 + M \times N \times D_f^2 \times t$$

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 \rightarrow increase the number of channels by t times \rightarrow activate ReLU6;
2. Depthwise convolution: 3×3 depthwise convolution \rightarrow ReLU6;
3. Projection phase: 1×1 pointwise convolution \rightarrow 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.

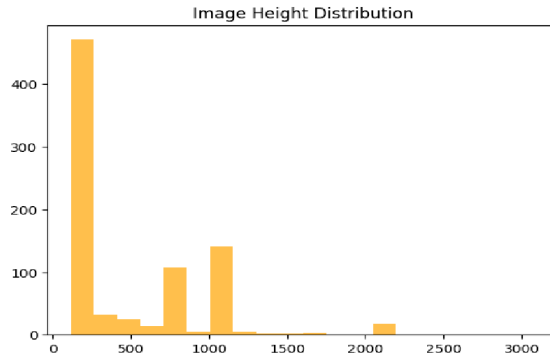


Figure 2 - Image Height Distribution.

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.

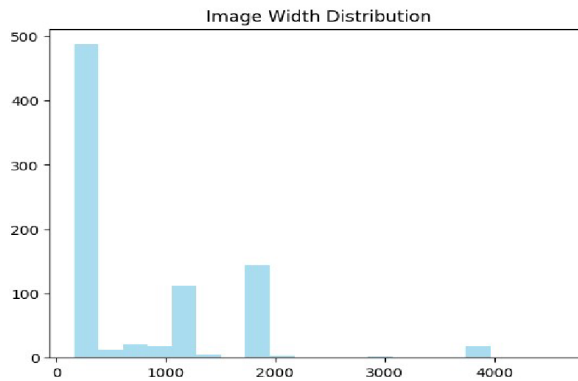


Figure 3 - Image Width Distribution

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).

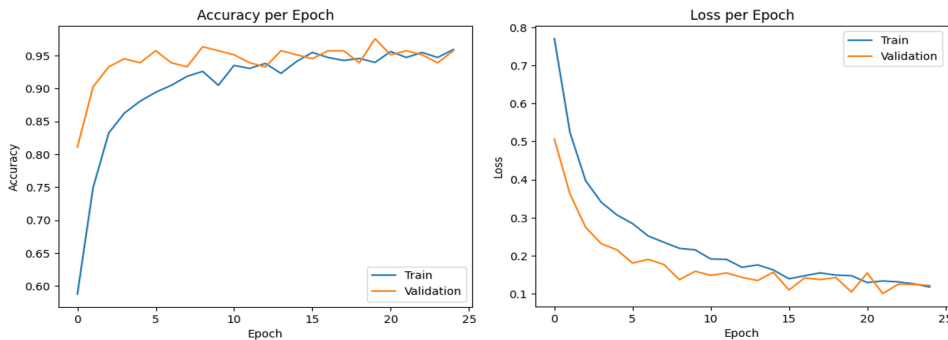


Figure 4 - Training and validation curves of the MobileNetV2 model: on the left – accuracy, on the right – loss.

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).

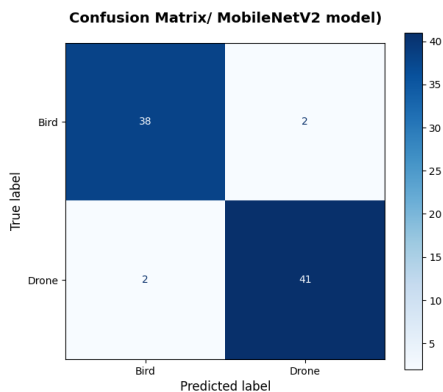


Figure 5 - Confusion matrix result of the MobileNetV2 model.

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).

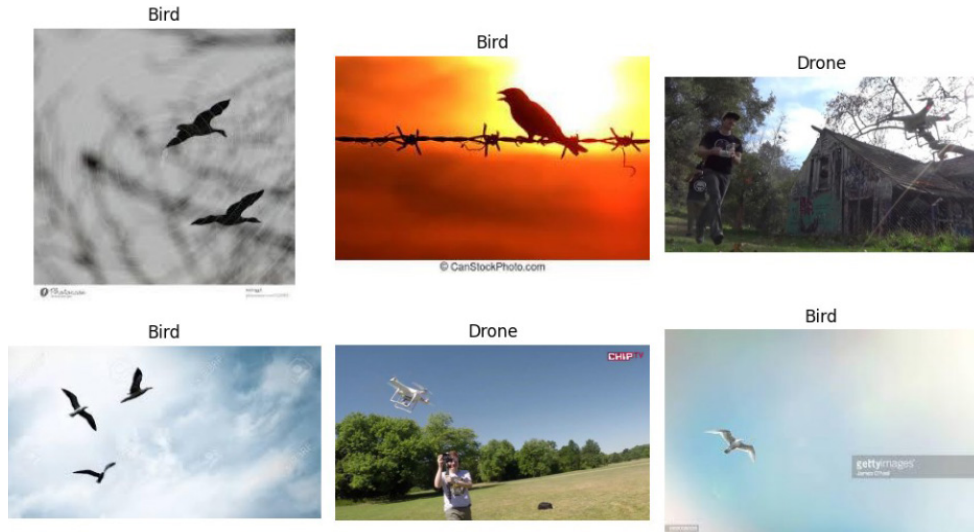


Figure 6 - Classification results of the MobileNetV2 model on sample images

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](https://doi.org/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](https://doi.org/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](https://doi.org/10.1109/ICICCS56967.2023.10142795) (in Eng.)
- AlDawasari 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. DOI: https://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.