

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

ҚАЗАҚСТАН РЕСПУБЛИКАСЫ
ҰЛТТЫҚ ҒЫЛЫМ АКАДЕМИЯСЫ

әл-Фараби атындағы Қазақ ұлттық университетінің

Х А Б А Р Л А Р Ы

ИЗВЕСТИЯ

НАЦИОНАЛЬНОЙ АКАДЕМИИ
НАУК РЕСПУБЛИКИ КАЗАХСТАН
Қазақстан Республикасының
Ғылым Академиясының
Әл-Фараби атындағы
Қазақ ұлттық университеті

NEWS

OF THE ACADEMY OF SCIENCES
OF THE REPUBLIC OF
KAZAKHSTAN
al-Farabi Kazakh National University

PHYSICO-MATHEMATICAL SERIES

1 (345)

JANUARY – MARCH 2023

PUBLISHED SINCE JANUARY 1963

PUBLISHED 4 TIMES A YEAR

ALMATY, NAS RK

БАС РЕДАКТОР:

МУТАНОВ Ғалымқайыр Мұтанұлы, техника ғылымдарының докторы, профессор, ҚР ҰҒА академигі, ҚР БҒМ ҚҰО ақпараттық және есептеу технологиялар институтының бас директорының м.а. (Алматы, Қазақстан), **Н=5**

РЕДАКЦИЯ АЛҚАСЫ:

КАЛИМОЛДАЕВ Мақсат Нұрәліұлы (бас редактордың орынбасары), физика-математика ғылымдарының докторы, профессор, ҚР ҰҒА академигі, ҚР БҒМ ҚҰО ақпараттық және есептеу технологиялар институты бас директорының кеңесшісі, зертхана меңгерушісі (Алматы, Қазақстан), **Н=7**

МАМЫРБАЕВ Өркен Жұмажанұлы (ғалым хатшы), Ақпараттық жүйелер саласындағы техника ғылымдарының (PhD) докторы, ҚР БҒМ ҚҰО ақпараттық және есептеу технологиялар институты директорының ғылым жөніндегі орынбасары (Алматы, Қазақстан), **Н=5**

БАЙГУНЧЕКОВ Жұмаділ Жанабайұлы, техника ғылымдарының докторы, профессор, ҚР ҰҒА академигі, Кибернетика және ақпараттық технологиялар институты, қолданбалы механика және инженерлік графика кафедрасы, Сәтбаев университеті (Алматы, Қазақстан), **Н=3**

ВОЙЧИК Вальдемар, техника ғылымдарының докторы (физ-мат), Люблин технологиялық университетінің профессоры (Люблин, Польша), **Н=23**

СМОЛАРЖ Анджей, Люблин политехникалық университетінің электроника факультетінің доценті (Люблин, Польша), **Н=17**

ӘМІРҒАЛИЕВ Еділхан Несіпханұлы, техника ғылымдарының докторы, профессор, ҚР ҰҒА академигі, Жасанды интеллект және робототехника зертханасының меңгерушісі (Алматы, Қазақстан), **Н=12**

КИЛАН Әлімхан, техника ғылымдарының докторы, профессор (ғылым докторы (Жапония), ҚР БҒМ ҚҰО ақпараттық және есептеу технологиялар институтының бас ғылыми қызметкері (Алматы, Қазақстан), **Н=6**

ХАЙРОВА Нина, техника ғылымдарының докторы, профессор, ҚР БҒМ ҚҰО ақпараттық және есептеу технологиялар институтының бас ғылыми қызметкері (Алматы, Қазақстан), **Н=4**

ОТМАН Мохаммед, PhD, Информатика, коммуникациялық технологиялар және желілер кафедрасының профессоры, Путра университеті (Селангор, Малайзия), **Н=23**

НЫСАНБАЕВА Сауле Еркебұланқызы, техника ғылымдарының докторы, доцент, ҚР БҒМ ҚҰО ақпараттық және есептеу технологиялар институтының аға ғылыми қызметкері (Алматы, Қазақстан), **Н=3**

БИЯШЕВ Рустам Гакашевич, техника ғылымдарының докторы, профессор, Информатика және басқару мәселелері институты директорының орынбасары, Ақпараттық қауіпсіздік зертханасының меңгерушісі (Қазақстан), **Н=3**

КАПАЛОВА Нұрсұлту Алдажарқызы, техника ғылымдарының кандидаты, ҚР БҒМ ҚҰО ақпараттық және есептеу технологиялар институтының киберқауіпсіздік зертханасының меңгерушісі (Алматы, Қазақстан), **Н=3**

КОВАЛЕВ Александр Михайлович, физика-математика ғылымдарының докторы, Украина Ұлттық Ғылым академиясының академигі, Қолданбалы математика және механика институты (Донецк, Украина), **Н=5**

МИХАЛЕВИЧ Александр Александрович, техника ғылымдарының докторы, профессор, Беларусь Ұлттық Ғылым академиясының академигі (Минск, Беларусь), **Н=2**

ТИГИНЯНУ Ион Михайлович, физика-математика ғылымдарының докторы, академик, Молдова Ғылым академиясының президенті, Молдова техникалық университеті (Кишинев, Молдова), **Н=42**

«ҚР ҰҒА Хабарлары. Информатика сериясы».

ISSN 2518-1726 (Online),

ISSN 1991-346X (Print)

Меншіктеуші: «Қазақстан Республикасының Ұлттық ғылым академиясы» РҚБ (Алматы қ.). Қазақстан Республикасының Ақпарат және қоғамдық даму министрлігінің Ақпарат комитетінде 14.02.2018 ж. берілген **№ 16906-Ж** мерзімдік басылым тіркеуіне қойылу туралы куәлік.

Тақырыптық бағыты: *физика-математикалық сериясы*.

Қазіргі уақытта: *«ақпараттық технологиялар» бағыты бойынша ҚР БҒМ БҒСБҚ ұсынған журналдар тізіміне енді.*

Мерзімділігі: *жылына 4 рет.*

Тиражы: *300 дана.*

Редакцияның мекен-жайы: *050010, Алматы қ., Шевченко көш., 28, 218 бөл., тел.: 272-64-39*

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

© Қазақстан Республикасының Ұлттық ғылым академиясы, 2023
Типографияның мекен-жайы: «Аруна» ЖК, Алматы қ., Мұратбаев көш., 75.

Главный редактор:

МУТАНОВ Галимкаир Мутанович, доктор технических наук, профессор, академик НАН РК, и.о. генерального директора «Института информационных и вычислительных технологий» КН МНВО РК (Алматы, Казахстан), **Н=5**

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), **Н=7**

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), **Н=5**

БАЙГУНЧЕКОВ Жумадил Жанабаевич, доктор технических наук, профессор, академик НАН РК, Институт кибернетики и информационных технологий, кафедра прикладной механики и инженерной графики, Университет Саптаева (Алматы, Казахстан), **Н=3**

ВОЙЧИК Вальдемар, доктор технических наук (физ.-мат.), профессор Люблинского технологического университета (Люблин, Польша), **Н=23**

СМОЛАРЖ Анджей, доцент факультета электроники Люблинского политехнического университета (Люблин, Польша), **Н=17**

АМИРГАЛИЕВ Едилхан Несипханович, доктор технических наук, профессор, академик Национальной инженерной академии РК, заведующий лабораторией «Искусственного интеллекта и робототехники» (Алматы, Казахстан), **Н=12**

КЕЙЛАН Алимхан, доктор технических наук, профессор (Doctor of science (Japan)), главный научный сотрудник РГП «Института информационных и вычислительных технологий» КН МНВО РК (Алматы, Казахстан), **Н=6**

ХАЙРОВА Нина, доктор технических наук, профессор, главный научный сотрудник РГП «Института информационных и вычислительных технологий» КН МНВО РК (Алматы, Казахстан), **Н=4**

ОТМАН Мохамед, доктор философии, профессор компьютерных наук, Департамент коммуникационных технологий и сетей, Университет Путра Малайзия (Селангор, Малайзия), **Н=23**

НЫСАНБАЕВА Сауле Еркебулановна, доктор технических наук, доцент, старший научный сотрудник РГП «Института информационных и вычислительных технологий» КН МНВО РК (Алматы, Казахстан), **Н=3**

БИЯШЕВ Рустам Гакашевич, доктор технических наук, профессор, заместитель директора Института проблем информатики и управления, заведующий лабораторией информационной безопасности (Казахстан), **Н=3**

КАПАЛОВА Нурсулу Алдажаровна, кандидат технических наук, заведующий лабораторией кибербезопасности РГП «Института информационных и вычислительных технологий» КН МНВО РК (Алматы, Казахстан), **Н=3**

КОВАЛЕВ Александр Михайлович, доктор физико-математических наук, академик НАН Украины, Институт прикладной математики и механики (Донецк, Украина), **Н=5**

МИХАЛЕВИЧ Александр Александрович, доктор технических наук, профессор, академик НАН Беларуси (Минск, Беларусь), **Н=2**

ТИГИНЯНУ Ион Михайлович, доктор физико-математических наук, академик, президент Академии наук Молдовы, Технический университет Молдовы (Кишинев, Молдова), **Н=42**

«Известия НАН РК. Серия информатики».

ISSN 2518-1726 (Online),

ISSN 1991-346X (Print)

Собственник: *Республиканское общественное объединение «Национальная академия наук Республики Казахстан» (г. Алматы).*

Свидетельство о постановке на учет периодического печатного издания в Комитете информации Министерства информации и общественного развития Республики Казахстан **№ 16906-Ж** выданное 14.02.2018 г.

Тематическая направленность: *серия физика-математическая.*

В настоящее время: *вошел в список журналов, рекомендованных ККСОН МОН РК по направлению «информационные коммуникационные технологии».*

Периодичность: *4 раз в год.*

Тираж: *300 экземпляров.*

Адрес редакции: *050010, г. Алматы, ул. Шевченко, 28, оф. 218, тел.: 272-64-39*

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

© Национальная академия наук Республики Казахстан, 2023
Адрес типографии: ИП «Аруна», г. Алматы, ул. Муратбаева, 75.

Chief Editor:

MUTANOV Galimkair Mutanovich, doctor of technical sciences, professor, academician of NAS RK, acting General Director of the Institute of Information and Computing Technologies CS MES RK (Almaty, Kazakhstan), **H=5**

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), **H = 7**

Mamyrbayev 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), **H = 5**

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), **H=3**

WOJCIK Waldemar, Doctor of Technical Sciences (Phys.-Math.), Professor of the Lublin University of Technology (Lublin, Poland), **H=23**

SMOLARJ Andrej, Associate Professor Faculty of Electronics, Lublin polytechnic university (Lublin, Poland), **H= 17**

AMIRGALIEV Edilkhan Nesipkhanovich, Doctor of Technical Sciences, Professor, Academician of NAS RK, Head of the Laboratory of Artificial Intelligence and Robotics (Almaty, Kazakhstan), **H= 12**

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), **H= 6**

KHAIROVA Nina, Doctor of Technical Sciences, Professor, Chief Researcher of the Institute of Information and Computational Technologies CS MES RK (Almaty, Kazakhstan), **H= 4**

OTMAN Mohamed, PhD, Professor of Computer Science Department of Communication Technology and Networks, Putra University Malaysia (Selangor, Malaysia), **H= 23**

NYSANBAYEVA Saule Yerkebulanovna, Doctor of Technical Sciences, Associate Professor, Senior Researcher of the Institute of Information and Computing Technologies CS MES RK (Almaty, Kazakhstan), **H= 3**

BIYASHEV Rustam Gakashevich, doctor of technical sciences, professor, Deputy Director of the Institute for Informatics and Management Problems, Head of the Information Security Laboratory (Kazakhstan), **H= 3**

KAPALOVA Nursulu Aldazharovna, Candidate of Technical Sciences, Head of the Laboratory cybersecurity, Institute of Information and Computing Technologies CS MES RK (Almaty, Kazakhstan), **H=3**

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), **H=5**

MIKHALEVICH Alexander Alexandrovich, Doctor of Technical Sciences, Professor, Academician of the National Academy of Sciences of Belarus (Minsk, Belarus), **H=2**

TIGHINEANU Ion Mihailovich, Doctor of Physical and Mathematical Sciences, Academician, President of the Academy of Sciences of Moldova, Technical University of Moldova (Chisinau, Moldova), **H=42**

News of the National Academy of Sciences of the Republic of Kazakhstan.

Series of informatics.

ISSN 2518-1726 (Online),

ISSN 1991-346X (Print)

Owner: RPA «National Academy of Sciences of the Republic of Kazakhstan» (Almaty). The certificate of registration of a periodical printed publication in the Committee of information of the Ministry of Information and Social Development of the Republic of Kazakhstan No. 16906-Ж, issued 14.02.2018

Thematic scope: *series physical-mathematical series.*

Currently: *included in the list of journals recommended by the CCSES MES RK in the direction of «information and communication technologies».*

Periodicity: *4 times a year.*

Circulation: *300 copies.*

Editorial address: *28, Shevchenko str., of. 218, Almaty, 050010, tel. 272-64-39*

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

© National Academy of Sciences of the Republic of Kazakhstan, 2023

Address of printing house: ST «Aruna», 75, Muratbayev str, Almaty.

NEWS OF THE NATIONAL ACADEMY OF SCIENCES
OF THE REPUBLIC OF KAZAKHSTAN
PHYSICO-MATHEMATICAL SERIES
ISSN 1991-346X

Volume 1, Number 345 (2023), 50-63
<https://doi.org/10.32014/2023.2518-1726.168>

© **A. Yerimbetova**^{1,3}, **E. Daiyrbayeva**^{1,2,3*}, **L. Cherikbayeva**^{1,4}, 2023

¹Institute of Information and Computational Technologies CS MES RK;

²Academy of Logistics and Transport, Almaty, Kazakhstan;

³Satbayev University, Almaty, Kazakhstan;

⁴Al-Farabi Kazakh National University, Almaty, Kazakhstan.
E-mail: nurbekkyzy_e@mail.ru

EMBEDDING HIDDEN INFORMATION IN IMAGES BASED ON BICUBIC INTERPOLATION

Yerimbetova Aigerim — PhD. Associate Professor. Institute of Information and Computational Technologies, prof., Satbayev University Almaty, Kazakhstan.

E-mail: aigerian@mail.ru, <https://orcid.org/0000-0002-2013-1513>;

Daiyrbayeva Elmira — research fellow, Institute of Information and Computational Technologies CS MES RK. Assist. prof. Satbayev University, Almaty, Kazakhstan.

E-mail: nurbekkyzy_e@mail.ru, <https://orcid.org/0000-0002-4255-5456>;

Cherikbayeva Lyailya — PhD. Assist. prof. Al Farabi Kazakh National University, research fellow, senior researcher, Institute of Information and Computational Technologies CS MES RK. Almaty, Kazakhstan.

E-mail: lyailya_sh@mail.ru, <https://orcid.org/0000-0001-8948-4205>.

Abstract. The article is devoted to the study of a well-known steganographic method using an interpolation algorithm. Image magnification algorithms directly affect the quality of image magnification. In this paper, the experiment was carried out on the basis of bicubic interpolation. Bicubic interpolation is most often used in image processing, giving a better picture compared to bilinear interpolation. Many authors have investigated this method, and a good review of existing works was made on our part. We also performed regular — singular value analysis (RS) and obtained the results, the steganographic algorithm is considered resistant to this type of steganalysis. Effective methods of entering hidden information into images using bicubic interpolation type are considered. Experiments were carried out and the results were presented in tabular forms for convenience. The results proved that this method will be used in the future. Also in this article, issues related to the construction of a secret communication channel by embedding hidden messages in digital content (image) were considered, the scope and secrecy of implementation were studied. The experimental results give the user recommendations on how to

use the algorithm to achieve optimal results in accordance with various fields of application. In the future, it is planned to introduce and investigate implementation methods using other interpolation methods.

Keywords: bicubic interpolation, steganography, images, steganalysis, secret message

© А.С. Еримбетова^{1,3}, Э.Н. Дайырбаева^{1,2,3*}, Л. Черикбаева^{1,4}, 2023

¹Ақпараттық және есептеуіш технологиялары институты;

²Логистика және көлік академиясы, Алматы, Қазақстан;

³Сәтбаев Университеті, Алматы, Қазақстан;

⁴ әл-Фараби атындағы ҚазҰУ, Алматы, Қазақстан.

E-mail: nurbekkyzy_e@mail.ru

БИКУБТЫҚ ИНТЕРПОЛЯЦИЯҒА НЕГІЗІНДЕ СУРЕТТЕРГЕ ЖАСЫРЫН АҚПАРАТТЫ ЕНГІЗУ

Еримбетова Айгерим Сембековна — PhD, қауымдас.профессор. Ақпараттық және есептеуіш технологиялар институты; проф. Сәтбаев университеті. Алматы, Қазақстан.

E-mail: aigerian@mail.ru, <https://orcid.org/0000-0002-2013-1513>;

Дайырбаева Эльмира Нурбекқызы — ғылыми қызметкер. Ақпараттық және есептеуіш технологиялар институты, аға оқытушы. Сәтбаев университеті, Алматы, Қазақстан.

E-mail: nurbekkyzy_e@mail.ru, <https://orcid.org/0000-0002-4255-5456>;

Черикбаева Ләйлә Шәріпқызы — PhD, доцент м.а., әл-Фараби атындағы ҚазҰУ, аға ғылыми қызметкер. Ақпараттық және есептеуіш технологиялар институты, Алматы, Қазақстан.

E-mail: lyailya_sh@mail.ru, <https://orcid.org/0000-0001-8948-4205>.

Аннотация. Мақала интерполяция алгоритмін қолдана отырып, белгілі стеганографиялық әдісті зерттеуге арналған. Кескінді үлкейту алгоритмдері кескінді үлкейту сапасына тікелей әсер етеді. Бұл жұмыста эксперимент бикубтық интерполяция негізінде жүргізілді. Бикубтық интерполяция көбінесе кескіндерді өңдеуде қолданылады, бұл екі сызықты интерполяциямен салыстырғанда жақсы кескін береді. Көптеген авторлар бұл әдісті зерттеді және біздің тарапымыздан бар жұмыстарға жақсы шолу жасалды. Біз сондай-ақ тұрақты сингулярлық мәндерді (RS) талдадық және нәтижелерін алдық, стеганографиялық алгоритм стеганализдің осы түріне төзімді болып саналады. Интерполяцияның бикубтық түрін қолдана отырып, суреттерге жасырын ақпаратты енгізудің тиімді әдістері қарастырылды. Эксперименттер жүргізілді және ыңғайлы болу үшін нәтижелер кестелік түрде ұсынылды. Алынған нәтижелер бұл әдістің болашақта қолданылатынын дәлелдеді. Сондай-ақ, бұл мақалада сандық суретке (кескінге) жасырын хабарламаларды енгізу арқылы құпия байланыс арнасын құруға қатысты мәселелер қарастырылды, іске асырудың ауқымы мен құпиялылығы зерттелді. Эксперимент нәтижелері пайдаланушыға әртүрлі қолдану орталарына сәйкес оңтайлы нәтижелерге қол жеткізу үшін алгоритмді қалай пайдалану керектігі туралы ұсыныстар береді.

Болашақта интерполяцияның басқа әдістерін қолдана отырып, іске асыру әдістерін енгізу және зерттеу жоспарлануда.

Түйін сөздер: бикубтық интерполяция, стеганография, суреттер, стеганализ, құпия хабарлама

© А.С. Еримбетова^{1,3}, Э.Н. Дайырбаева^{1,2,3*}, Л. Черикбаева^{1,4}, 2023

¹Институт информационных и вычислительных технологии КН МНВО РК;

²Академия логистики и транспорта, Алматы, Казахстан;

³Satbayev University, Алматы, Казахстан;

⁴КазНУ им. аль-Фараби, Алматы, Казахстан.

E-mail: nurbekkyzy_e@mail.ru

ВНЕДРЕНИЕ СКРЫТОЙ ИНФОРМАЦИИ В ИЗОБРАЖЕНИИ НА ОСНОВЕ БИКУБИЧЕСКОЙ ИНТЕРПОЛЯЦИИ

Еримбетова Айгерим Сембековна — PhD, ассоц.проф. Институт информационных и вычислительных технологии, проф. Satbayev University. Алматы, Казахстан.

E-mail: aigerian@mail.ru, <https://orcid.org/0000-0002-2013-1513>;

Дайырбаева Эльмира Нурбеккызы — научный сотрудник, Институт информационных и вычислительных технологии; ассист.проф., Академия логистики и транспорта; ст.преп. Satbayev University, Алматы, Казахстан.

E-mail: nurbekkyzy_e@mail.ru, <https://orcid.org/0000-0002-4255-5456>;

Черикбаева Ляйля Шариповна — PhD, и.о. доцента. КазНУ им. аль-Фараби. СИС. Институт информационных и вычислительных технологии, Алматы, Казахстан.

E-mail: lyailya_sh@mail.ru, <https://orcid.org/0000-0001-8948-4205>.

Аннотация. Статья посвящена исследованию хорошо известного стеганографического метода с использованием алгоритма интерполяции. Алгоритмы увеличения изображения напрямую влияют на качество увеличения изображения. В данной работе эксперимент был проведен на основе бикубической интерполяции. Бикубическая интерполяция чаще всего используется при обработке изображений, давая лучшее изображение по сравнению с билинейной интерполяцией. Многие авторы исследовали этот метод, и с нашей стороны был сделан хороший обзор существующих работ. Мы также выполнили анализ регулярных сингулярных значений (RS) и получили результаты, стеганографический алгоритм считается устойчивым к этому типу стеганализа. Рассмотрены эффективные методы ввода скрытой информации в изображения с использованием бикубического типа интерполяции. Были проведены эксперименты, и результаты для удобства были представлены в табличной форме. Результаты доказали, что этот метод будет использоваться в будущем. Также в этой статье были рассмотрены вопросы, связанные с построением секретного канала связи путем встраивания скрытых сообщений в цифровой контент (изображение), изучены масштабы и секретность реализации. Результаты эксперимента дают пользователю рекомендации о

том, как использовать алгоритм для достижения оптимальных результатов в соответствии с различными областями применения. В будущем планируется внедрить и исследовать методы реализации с использованием других методов интерполяции.

Ключевые слова: бикубическая интерполяция, стеганография, изображения, стеганализ, секретное сообщение

Introduction

There is an enormous amount of media content being transmitted on the Internet. Much of this data is a source of income for its creator and is seen as an object of copyright protection. Given the ease and zero cost of reproduction (creation of a copy) of any file, there is a need to trace its path (from the creator to the end consumer, including the unlicensed one). One of the most effective solutions to this problem is the use of steganography techniques, which use secret messages embedded in the file. Such messages can either identify the author (digital watermarks) or the end user (digital fingerprint) (Daiyrbayeva et al., 2021; Cherikbayeva et al., 2021).

In scientific publications there are works aimed at creating new methods of embedding and at creating new methods of detection (stegoanalysis). The latter are used to detect the facts of information leakage, for example, through official correspondence. Thus, there is an urgent need to analyze existing infiltration methods and create new and effective methods of infiltration of hidden messages (Daiyrbayeva and Yerimbetova, 2021)

Given that the most common type of files transmitted on the Internet are pictures, then the current study focused on the introduction of hidden information in images. Thus, one of the modern approaches of steganography is based on interpolation methods. In particular, the application of interpolation techniques for message embedding, which, in a sense, is a discrete analogue of a hologram, and is commonly used to recover signals and images that have been affected and have resulted in a large loss of information, is investigated (Berikov et al., 2021; Singh et al., 2019).

There are many algorithms for increasing the resolution and scaling of digital images. The simplest methods, called linear ones, perform interpolation using polyphase filtering. This class includes the nearest neighbor method, bilinear and bicubic interpolation, the Lanczos filter, etc (Vaganov et al., 2016)

Popular image zoom methods are methods based on pixel color interpolation. The principle of operation is that for each point of the final image, a fixed set of points of the original image is taken and interpolated in accordance with its mutual position and the selected filter. The number of points also depends on the filter. A degenerate case of interpolation methods is the nearest neighbor method.

If steganography aims at imperceptibly transmitting data embedded in an image so that the fact of embedding itself remains unnoticed, then steganographic analysis (steganalysis) is aimed at detecting embedded data, i.e. the fact of

embedding. Computer steganography involves the introduction of data into almost any container, data loss is possible (bmp, gif, jpeg, etc). In practice, the most common method is the introduction of data into digital images, at the same time, the steganalysis of digital images is the simplest and most studied, so all the methods under consideration will be shown by the example of images. Also, a container means an object in which data was embedded to hide. Many methods of steganalysis are based on detecting deviations of the observed multimedia information (stego) from its expected model. The class of statistical methods of steganalysis uses a variety of statistical characteristics, such as: entropy estimation, correlation coefficients, probability of occurrence and dependencies between elements of sequences, conditional distributions, distinguishability of distributions according to the Chi-square criterion, and many others. Simple tests evaluate the correlation dependencies of container elements into which hidden messages can be embedded.

When studying the issues of image steganalysis, a comprehensive analysis of existing works was carried out.

The article (Dryuchenkoe et al., 2022) discusses the problem of digital image steganalysis. The authors presented a new approach based on the use of deep convolutional neural networks with a relatively simple architecture, characterized by the use of additional levels of special processing. Experiments were carried out for several well-known stego algorithms (including the classical block and block-spectral Kutter, Koh–Zhao algorithms, modern EMD, MBEP algorithms and WOW and S-UNIWARD adaptive spatial steganography algorithms) and for stego algorithms based on the use of heteroassociative compression transformations.

The article (Nechta, 2019) discusses the development of a new method for embedding hidden messages in various containers (text, executable files). A new method of steganographic transformation of a binary message is presented, which allows embedding hidden data. It is proposed to convert a message taken from an empty container. The original message is processed as a set of two-bit elements. A sequence of non-repeating elements, called a series, is used to embed a secret message. The embedding was done by rearranging the elements inside the string. The proposed algorithm allows you to simulate the statistical features of a message taken from an empty container, which reduces the likelihood of successful steganalysis. During the experiment, the statistical properties of the message taken from the container before and after embedding were investigated. The analysis was carried out using previously known steganalysis methods based on the detection of statistical differences in messages taken from empty and filled containers. But the use of this algorithm for images is not taken into account.

The article (Agaian et al., 2004) presents a new approach that focuses on the following problems: detection and localization of informative stego areas in digital clean and noisy images; removal of hidden data along with minimizing statistical differences between stego images and a deleted image with stego information. The

new approach presented by the authors is based on a new pixel comparison and a new dimension of complexity. Also, this new measure identifies informative and wall-like areas of the image for the purpose of steganalysis by preserving informative areas and discarding stegoid areas. According to the authors, this method can be used to compress data and conceal classified information in both temporary and transformed areas. It is necessary to pay attention to the fact that it does not depend on the order of color vectors in the palette.

In the work of the authors (Vovk et al., 2015), a proprietary method of embedding information in still images is proposed. The new algorithm used additional cropping and stability blocks during the previous image processing. A comparative analysis of the existing and proposed steganographic system based on quantitative and qualitative characteristics was also carried out. The synthesized method showed excellent results relative to the most common methods and resistance to statistical steganalysis, without detecting significant deviations of the calculated parameters.

The purpose of this work is to investigate the bicubic interpolation method by conducting steganalysis by available means. To conduct the research, we will use RS analysis as the main method of image steganalysis.

Methods and materials

Image scaling is one of the classical problems of computer graphics. A special case of this problem is to reduce and increase the image size by half. These methods play a special role in the compression of raster images, where the overall coding efficiency depends on the quality of approximation.

In this paper, we will investigate a shorthand algorithm for embedding information into digital images using bicubic interpolation.

During the study, an analysis was made of the existing works of authors who are engaged in the study of interpolation, in particular bicubic interpolation:

In the work (Vaganov, Khashin, 2016), a comparative analysis of the quality of some interpolation non-adaptive methods of doubling the image size was carried out. The value of the standard deviation was used as an estimate of the accuracy (quality) of the approximation. The description of interpolation doubling algorithms is given, such as: the nearest neighbor method, linear and cubic interpolation, convolution interpolation with the Lanczos kernel (for $a=1, 2, 3$), as well as the 17-point interpolation method.

Also in the work (Veselov et al., 2010) the questions of interpolation are investigated. The results obtained in the work will help to create detailed methods for assessing the quality of digital images obtained by modern digital aerial photography systems, as well as to evaluate the technical characteristics of the latter using various types of dashed test polygons.

The article (Trubakov et al., 2017) describes the issues of effective scaling of raster images. The reasons for the appearance of negative effects that occur when increasing the resolution of raster images are considered and analyzed. The efficiency of such methods as the nearest neighbor method, bilinear interpolation

and bicubic interpolation is analyzed. The method of experimental research is considered, the results of comparing algorithms for the quality of the images obtained and the speed are presented. The result of the study is recommendations on the choice of algorithms for increasing the resolution of images.

The paper (Dangwen et al., 2010) discusses the issues of image interpolation. Image interpolation is a method of obtaining a high-resolution image from its low-resolution counterpart, which is often required in many image processing tasks. In this paper, the authors propose edge-oriented bicubic convolution interpolation (BC). The proposed method can adapt well to changing edge structures of images. Experimental results show that this reduces common artifacts such as blurring, blocking and ringing, etc., and significantly exceeds some existing interpolation methods (including BC interpolation) in terms of both subjective and objective indicators.

The authors (Yingmin et al., 2019) in the article considered a bicubic algorithm for image scaling. The bicubic algorithm has the advantages of more accurate image magnification and higher processing speed. Currently, bicubic amplification technology is used in many image processing programs. The authors proposed an improved bicubic interpolation algorithm. Unlike the traditional algorithm, which sets the key parameter a to -0.5 to guarantee a third-order Taylor approximation, we remove such a requirement, since this value is applicable only to the interpolation of a flat area, while the change in the pixel value of the image is often irregular by direct optimization of the standard deviation of the image, we obtain an optimization function of a higher order. At the same time, a new variable is introduced to replace the a^2 term of the optimization function, so that a higher-order optimization problem can be transformed into a least squares problem. Experiments show that optimized parameters have a better reconstruction effect, and obtaining optimized parameters is directly related to image magnification, and the image itself has little effect.

In the article (Watchara Ruangsang et al., 2017), experimental results are verified using processing time and reconstructed images that can be used in real-time applications.

The authors (Shengkui Gao, 2011) present methods of bilinear and bicubic interpolation adapted for the separation of the image polarization sensor in the focal plane. This article discusses five interpolation methods: bilinear, weighted bilinear, bicubic spline, approximated bicubic spline and bicubic interpolation method. The modulation transfer function analysis is applied to various interpolation methods, and test images as well as numerical error analysis are also presented. Based on the comparison results, full-frame bicubic spline interpolation provides the best performance for polarizing images.

The paper (Yongxing Zhang et al., 2022) presents traditional methods of image sampling reduction aimed at removing smoothing artifacts. However, the effect on the quality of an image interpolated from an image with reduced sampling is usually neglected. To solve this problem, the authors propose an interpolation-dependent

downsampling of the image, where interpolation is associated with downsampling. Numerous experimental results demonstrate the viability and effectiveness of the method proposed by the authors.

Basically, any stage of digital image processing has an impact on its quality. Currently, popular methods of image scaling are methods based on pixel color interpolation. The principle of operation is as follows, i.e., for each point of the final image, a fixed set of points of the original image is taken and interpolated in accordance with their mutual position and the selected filter. The number of points also depends on the filter (Sazonov et al., 2013).

The essence of interpolation is to use the available data to obtain the expected values at unknown points. Image interpolation works in two dimensions and tries to achieve the best approximation in pixel color and brightness based on the values of the surrounding pixels (Ki – Hyun Jung, 2009; Bialas-Cie'z and Calvi, 2012).

The simplest type of interpolation method is as follows: $n+1$ at the point of the segment $[a,b]$, the interpolation node is $x_i (i=0,1,2,\dots,n)$ and the values of the $f(x)$ function are given at these points: $f(x_0) = y_0, f(x_1) = y_1, \dots, f(x_n) = y_n$.

Bicubic interpolation is in computational mathematics an extension of cubic interpolation to the case of a function of two variables whose values are given on a two — dimensional regular grid. The surface obtained as a result of bicubic interpolation is a smooth function on the boundaries of neighboring squares, unlike surfaces obtained as a result of bilinear interpolation or nearest neighbor interpolation (Kameneva, 2016).

One of the methods of bicubic interpolation is sequential cubic interpolation, the value of the function f is found by the formula (Eq.1):

$$f(x, y) = [1yy^2y^3]A \begin{bmatrix} f(1,-, -1) & f(0, -1) & f(1, -1) & f(2, -1) \\ f(0, -1) & f(0, 0) & f(1, 0) & f(2, 0) \\ f(1, -1) & f(0, 1) & f(1, 1) & f(2, 1) \\ f(2, -1) & f(0, 2) & f(1, 2) & f(2, 2) \end{bmatrix} A^T \begin{bmatrix} 1 \\ x \\ x^2 \\ x^3 \end{bmatrix} \quad (1)$$

One of the main methods of statistical steganalysis is the RS method, which was developed by Friedrich et al. in 2001.

The method is based on the analysis of disjoint groups of n adjacent pixels, n is even (Fridrich, 2001). After selecting the groups, a regularity function is introduced — a function that matches one real number to one group and shows the regularity of the pixels of the group. The value of the regularity function should be the greater the noisier the pixel group is.

As a function of regularity, the sum of the absolute differences (the sum of the differences in values) of the neighboring pixels of the group is selected (Eq.2):

$$f(G) = f(g_1, g_2, \dots, g_n) = \sum_{i=1}^{n-1} |g_{i+1} - g_i| \quad (2)$$

Where G is a group of pixels; g_i – is the i^{th} element of the group of pixels G ; n is the number of pixels in the group.

After calculating the values of the regularity function for all groups of the analyzed image, a group of flip functions («flipping functions») is determined.

The main feature of the RS — method is that it analyzes the quantitative characteristics of small groups of pixels. In this connection, although it is not able to detect the area of potential embedding, it can detect an autopsy performed in random bits, and not sequentially (Vilkhovskiy, 2020).

The RS analysis method is used to detect LSB embedding and uses a sensitive method – double statistics obtained from spatial correlations in images (Swain, 2022; Sahu et al., 2019; Daiyrbayeva et al., 2022).

Results

To conduct the experiment, a program was written in the Python environment.

First, a picture is fed to the input, then the bicubic interpolation method was used to enlarge the picture. The following steps describe the use of this method:

Connect the file where this method is written in the form of code.

```
import cv2
import numpy as np
import math as m
import sys, time

# Interpolation kernel
def intp(x, y):
    if (int(x) == 0) & (int(y) == 0):
        return ((x+1)**2*(x+1)**2)-(x+1)**2*(x+1)**2)

    elif (int(x) == 1) & (int(y) == 1):
        return (x**2*(x+1)**2)-(x**2)**2*(x+1)**2)

    return 0

def intp(img, M, W, C):
    img = cv.cvtColor(img, cv.COLOR_BGR2RGB)
    img = cv.resize(img, (W, H), interpolation=cv.INTER_CUBIC)

    # Pad the first/last two col and row
    img = cv.pad(img, (2, 2), cv_2c=(0, 0), cv_2c=(0, 0))
    img = cv.cvtColor(img, cv.COLOR_RGB2BGR)
    img = cv.pad(img, (2, 2), cv_2c=(0, 0), cv_2c=(0, 0))

    # Pad the missing eight pixels
    img = cv.pad(img, (2, 2), cv_2c=(0, 0), cv_2c=(0, 0))
    img = cv.cvtColor(img, cv.COLOR_BGR2RGB)
    img = cv.pad(img, (2, 2), cv_2c=(0, 0), cv_2c=(0, 0))

    return img

# Bicubic operation
def bicubic(img, ratio, w):
    # Get image size
    H, W, C = img.shape

    # Here H = height, W = width
    # C = Number of channels of the image in colour
    img = intp(img, H, W, C)

    # Create new image
    out = cv.cvtColor(img, cv.COLOR_RGB2BGR)
    out = cv.cvtColor(out, cv.COLOR_BGR2RGB)

    # Resizing into matrix
    out = cv.cvtColor(out, cv.COLOR_RGB2BGR)
```

Fig.1 From interpolation, import bicubic

In Fig.1, we take the bicubic method from a file called interpolation, where the logic of enlarging the image is written.

2. We use the cv2 library to read/write the image.

import cv2

3. Create a path string and assign the location of the image there as a string, for example, as “res_img/interpolated-without-secret/test.png”.

path = “res_img/interpolated-without-secret/test.png”

4. Create the `img` variable, where we will store the pixel value as an array using the `cv2` library.

```
img = cv2.imread(path)
```

in the `cv2` library there is an `imread` method – for reading an image that takes the location of the image. That's where we sell our path.

5. As soon as we read the image and turned the pixel value into an array, we store the response received through the bicubic method in the new variable `interpolated`.

```
Interpolated = bicubic (img, a, b)
```

the bicubic function takes 3 parameters as image, scale and coefficient!

To embed a secret message in our interpolated image, the method «embedding a symbol through the k^{th} step» was used. This is a fairly simple method. The meaning of this method is to select the optimal step for embedding.

Actually, we will describe the steps of encoding and decoding.

Coding Steps:

1. Get the location of the interpolated image, determine which pixel will change (R,G,B).

2. Get the message.

3. Choose step k .

4. We run through all the pixels and through the k^{th} step we symbolically change the pixel value to the ASCII character code.

5. As we change the value of the last character to the current pixel, the value of the next pixel will be stop – 0.

6. We return the modified image as an array.

Decoding Steps:

1. Get the location of the interpolated image.

2. Choose step k

3. We run through all the pixels and after the k^{th} step we take the pixel value by character, change them from ASCII code to a character.

4. Finish the stop loop – 0.

5. Return the hidden message.

Encoding and decoding is spelled out as a function. Encoding takes three parameters: the location of the image, the message and the step. Decoding takes only two parameters: the location of the image and the step.

The choice of the optimal step depends on you; I would suggest a LCD (the Largest Common Divisor).

To evaluate the steganographic algorithm based on bicubic interpolation, we will use the RS method.

When using the RS method, we introduce the concept of a container. A container is any information intended to hide a message. The choice of the type of container has a significant impact on the reliability of the stegosystem and the possibility of detecting the fact of transmission of a hidden message. When working, a visual container was used. A visual container is a picture or photograph in which small

changes in the brightness of predefined image raster points are used to embed messages.

The empirical capacity of a container is the maximum amount of information that can be written to the container when using the embedding method. The analyzing RS – analysis program outputs the amount of embedded information (L) as a percentage of the empirical capacity of the container, which is calculated as when embedded (Fig. 2).



Fig2. RS analysis implementation window

The maximum container capacity in the experiment is 12% and depends on the image.

During the study, 500 (Digital image interpolation, 2021) images of the size 225x225 were used. The results of calculating the type I error are shown in Table 1, where it is shown that the error is 0%. The results of RS analysis are shown in Table 2, according to which it can be seen that the method is relatively resistant to RS analysis.

Table 1 – RS analysis on a set of empty containers (500 images)

L		0%	1-4%	5% or more
File share	225x225	50	49,6	0,4

Table 2 – RS analysis on a set of containers filled using the bicubic interpolation method by 12%

L		0%	1-4%	5% or more
File share	225x225	33,6	64,2	2,2

Obviously, the less information we embed in the image, the less likely it is that detectable features will appear as a result of the implementation process.

Also in the conducted study, we determined the volume of containers filled using the bicubic interpolation method by 12% (Table 3).

Table 3 – Volume of containers filled using the interpolation method by 12%

Archiver	Volume of empty containers	Volume of filled containers
RAR	107MB	141MB
ZIP	187MB	198MB
GZIP	188MB	199MB
BZIP2	156MB	174MB

Discussion

We experimentally implemented bicubic interpolation. A stegoanalysis of this embedding method was carried out, and results were obtained that can be compared with the stegoanalysis of the methods considered in the work (Merzlyakova, 2011).

Based on the results of the study on a set of 500 images of size 225x225, we determined that the percentage of embedding is 12%. The obtained results of calculating the type I error (the case when a filled container is recognized as empty) showed that the error is 0%. The final results of the RS analysis are shown in Table 2, according to which it can be seen that this method is resistant to the RS method and is comparable in durability and capacity with the stegosystem of the permutation method for raster images considered in the work (Merzlyakova, 2011).

Conclusion

The most common interpolation method is bicubic, in which all surrounding pixels are examined for information to create new interpolated pixels. We have implemented and researched a steganographic algorithm based on bicubic interpolation. Based on these principles, a steganalysis of this embedding method was carried out and the results were obtained.

Also, during the study, issues related to the construction of a secret communication channel by embedding hidden messages in digital content (image) were considered, the scope and secrecy of implementation were studied.

In the future, it is planned to implement and investigate implementation methods using other interpolation methods.

REFERENCES

Agaian S.S., Rodriguez B.M., 2004 — *Agaian S.S., Rodriguez B.M.* Dietrich G. Steganalysis using modified pixel comparison and complexity measure. Proceedings of SPIE - The International Society for Optical Engineering, 5306. Pp. 46–57. DOI: 10.1117/12.526301.

Berikov V.B., Cherkbayeva L.S. 2018 — *Berikov V.B., Cherkbayeva L.S.* Searching for optimal classifier using a combination of cluster ensemble and kernel method. Optimization Problems and Their Applications, CEUR Workshop Proceedings. – Pp. 45–60.

Bialas-Cie'z L. and Calvi J.-P., 2012 — *Bialas-Cie'z L. and Calvi J.-P.* Pseudo Leja sequences. Ann. Mat. Pura e Appl. Pp. 53–75.

Cherikbayeva L., Yerimbetova A., Daiyrbayeva E., 2021 — *Cherikbayeva L., Yerimbetova A., Daiyrbayeva E.* Research of Cluster Analysis Methods for Group Solutions of the Pattern Recognition Problem. Proceedings - 6th International Conference on Computer Science and Engineering, UBMK 2021, Ankara-Turkey/ IEEE Xplore (Scopus). Pp.494-497. DOI 10.1109/UBMK52708.2021.9558884.

Daiyrbayeva E., Yerimbetova A., Toigozhinova A., Maratov Zh., Sambetbayeva M., 2021 — *Daiyrbayeva E., Yerimbetova A., Toigozhinova A., Maratov Zh., Sambetbayeva M.* Learning steganography with a strip transform. Proceedings – 6th International Conference on Computer Science and Engineering, UBMK 2021, Ankara-Turkey/ IEEE Xplore (Scopus). Pp.195–198. DOI 10.1109/UBMK52708.2021.9558892.

Daiyrbayeva E., Yerimbetova A., 2021 — *Daiyrbayeva E., Yerimbetova A.* Comparative analysis of the results of image recovery based on the strip method using various matrices. Of the National Academy of sciences of the Republic of Kazakhstan physico-mathematical. Volume 4. Pp. 29–34. <https://doi.org/10.32014/2020.2518-1726.63>.

Daiyrbayeva E., Yerimbetova A., Nechta I., Merzlyakova E., Toigozhinova A., Turganbayev A., 2022 — *Daiyrbayeva E., Yerimbetova A., Nechta I., Merzlyakova E., Toigozhinova A., Turganbayev A.* A Study of the Information Embedding Method into Raster Image Based on Interpolation. J. Imaging, 8, 288. <https://doi.org/10.3390/jimaging8100288>.

Digital image interpolation [Elektronnyy resurs]. Access mode: URL: https://disk.yandex.ru/d/ZHx4FV3t1t_T5g

Dryuchenko M.A., Sirota A.A., 2022 — *Dryuchenko M.A., Sirota A.A.* Image steganalysis using deep neural networks and heteroassociative integral transformations, Prikladnaya Diskretnaya Matematika, (55). Pp. 35–58. DOI: 10.17223/20710410/55/3.

Fridrich J., Golja M., Du R., 2001 — *Fridrich J., Golja M., Du R.* Reliable Detection of LSB Steganography in Color and Grayscale Images. Proceedings of the 2001 workshop on Multimedia and security: new challenges. Pp. 27–30. URL: <https://doi.org/10.1145/1232454.1232466>.

Gao S., Gruev V., 2011 — *Gao S., Gruev V.* Bilinear and bicubic interpolation methods for division of focal plane polarimeters //Optics express. – T. 19. – №. 27. – С. 26161–26173.

Kameneva A., 2016 — *Kameneva A.* Some methods of image interpolation. Scientific community of students: Collection of materials X International Student Scientific and Practical Conference, Cheboksary. – Cheboksary: Limited Liability Company «Center for Scientific Cooperation «Interactive Plus». Pp. 121–123.

Ki-Hyun Jung, Kee-Young Yoo., 2009 — *Ki-Hyun Jung, Kee-Young Yoo.* Data hiding method using image interpolation. Computer Standards & Interfaces.-Volume 31, Issue 2.2009. Pp. 465–470. <http://dx.doi.org/10.1016/j.csi.2008.06.001>.

Merzlyakova Ye., 2011 — *Merzlyakova Ye.* Postroyeniye steganograficheskikh sistem dlyarastrovy khizobra-zheniy, baziruyushchikh sya-nateoretiko-informatsionnykh printsipakh.: dis. ... kand. tekhn. nauk: 05.13.19. – Novosibirsk: SibGUTI–161p. URL: <https://www.dissertat.com/content/postroenie-steganograficheskikh-sistem-dlya-rastrovykh-izobrazhenii-baziruyushchikh-nya-na-te.> (in Russ).

Nechta I.V., 2019 — *Nechta I.V.* A method of steganographic message transformation with the partial antidisturbance property (2019) Journal of Computational Technologies, 24 (3). Pp. 75–87. DOI: 10.25743/ICT.2019.24.3.00

Sahu A.K., Swain G., 2019 — *Sahu A.K., Swain G.* Data hiding using adaptive LSB and PVD technique resisting PDH and RS analysis. International Journal of Electronic Security and Digital Forensics, 11 (4). Pp. 458–476. DOI: 10.1504/IJESDF.2019.102567.

Sazonov V. et al., 2013 — *Sazonov V., et al.* Scaling of digital images //Problems of automation and control in technical systems : Collection of articles of the International Scientific and Technical Conference, Penza. April 23–25. 2013 / edited by M.A. Shcherbakov. – Penza: Penza State University. – Pp. 170–173.

Singh A., Singh J., 2019 — *Singh A., Singh J.* Review and Comparative analysis of various Image Interpolation Techniques. 2nd International Conference on Intelligent Computing, Instrumentation and Control Technologies, ICICICT 2019, art. no. 8993258. Pp. 1214–1218. DOI: 10.1109/ICICICT46008.2019.8993258.

Swain G., Pradhan A., 2022 — *Swain G., Pradhan A.* Image Steganography Using Remainder Replacement, Adaptive QVD and QVC. *Wireless Personal Communications*, 123 (1). Pp. 273–293. DOI:10.1007/s11277-021-09131-6.

Trubakov A.O., Seleikovich M.O., 2017 — *Trubakov A.O., Seleikovich M.O.* Comparison of interpolation methods for scaling raster images // *Scientific and Technical Bulletin of the Bryansk State University*. No. 1. URL: <https://cyberleninka.ru/article/n/sravnenie-interpolyatsionnyh-metodov-masshtabirovaniya-rastrovyyh-izobrazheniy> (accessed: 20/11/2022). (in Russ).

Vaganov S.E., Khashin S.I., 2016) — *Vaganov S.E., Khashin S.I.* Comparison of image size doubling algorithms», *Modeling and Analysis of Information Systems*. Pp. 389–400 (in Russ).

Veselov Yu.G., Ostrovsky A.S., 2010 — *Veselov Yu.G., Ostrovsky A.S.* On the issue of assessing the resolution when scaling digital images // *Mechanical engineering and computer technologies*. No.06. URL: <https://cyberleninka.ru/article/n/k-voprosu-otsenki-razreshayushey-sposobnosti-primasshtabirovaniya-tsifrovyyh-izobrazheniy> (date of application: 11.11.2022) (in Russ).

Vilkhovskiy D.E., 2020 — *Vilkhovskiy D.E.* Review of methods of steganographic image analysis in the works of foreign authors. *Mathematical structures and modeling*. – No. 4(56). – Pp. 75–102. DOI: 10.24147/2222-8772.2020.4.75-102. (in Russ).

Vovk O., Astrakhantsev A., 2015 — *Vovk O., Astrakhantsev A.* New steganographic method: Development and comparison with the most relevant, 2nd International Scientific-Practical Conference Problems of Infocommunications Science and Technology, PIC S and T. - Conference Proceedings. Pp. 237–240. DOI: 10.1109/INFOCOMMST.2015.7357323.

W. Ruangsang and S. Aramvith, 2017 — *W. Ruangsang and S. Aramvith.* Efficient super-resolution algorithm using overlapping bicubic interpolation, *IEEE 6th Global Conference on Consumer Electronics (GCCE)*, Nagoya, Japan, 2017. Pp. 1–2. DOI: 10.1109/GCCE.2017.8229459.

Yingmin Li, F. Qi and Y. Wan, 2019 — *Yingmin Li, F. Qi and Y. Wan.* Improvements On Bicubic Image Interpolation, *2019 IEEE 4th Advanced Information Technology, Electronic and Automation Control Conference (IAEAC)*, Chengdu, China, 2019. Pp. 1316–1320. DOI: 10.1109/IAEAC47372.2019.8997600.

Yongxin Zhang, 2022 — *Yongxin Zhang.* Interpolate WRF data on Mercator projection to Cartesian grid. *IEEE IGARSS 2022*. https://www.igarss2022.org/view_paper.php?PaperNum=2081#top.

Dengwen Z., 2010 — *Dengwen Z.* An edge-directed bicubic interpolation algorithm, 3rd International Congress on Image and Signal Processing, Yantai, China. Pp. 1186–1189. DOI: 10.1109/CISP.2010.5647190.

МАЗМҰНЫ

Ж.К. Абдугулова, Г.А. Ускенбаева, М.Н. Глеген, А.К. Шукирова ҚҰБЫР ЖАБДЫҒЫНДА МАЙДЫ ҚЫЗДЫРУДЫҢ ТЕХНОЛОГИЯЛЫҚ ПРОЦЕСІН АВТОМАТТАНДЫРУ.....	5
Ж.С. Авкурова, С. Гнатюк, Л.М. Кыдыралина, Н.К. Курмангалиева АҚПАРАТТЫҚ-КОММУНИКАЦИЯЛЫҚ ЖҮЙЕЛЕРДЕ ҚҰҚЫҚ БҰЗУШЫНЫ ЕРТЕ АНЫҚТАУ ЖӘНЕ СӘЙКЕСТЕНДІРУДІҢ ИНТЕЛЛЕКТУАЛДЫ ӘДІСІ.....	22
А. Бекарыстанкызы, Ө. Ж. Мамырбаев АГГЛЮТИНАТИВТІ ТІЛДЕРГЕ АРНАЛҒАН СӨЙЛЕУДІ АВТОМАТТЫ ТҮРДЕ ТАҢУ ЖҮЙЕСІ.....	37
А.С. Еримбетова, Э.Н. Дайырбаева, Л. Черикбаева БИКУБТЫҚ ИНТЕРПОЛЯЦИЯҒА НЕГІЗІНДЕ СУРЕТТЕРГЕ ЖАСЫРЫН АҚПАРАТТЫ ЕНГІЗУ.....	50
М.Б. Есенова, Г.Б. Абдикеримова, А. Толстой, Ж.Б. Ламашева, А.А. Некесова БИДАЙДАҒЫ АРАМШӨПТЕР ОШАҒЫН АНЫҚТАУ ҮШІН ТЕКСТУРАЛЫҚ БЕЛГІЛЕР ӘДІСТЕРІН ҚОЛДАНУ.....	64
Л.З. Жолшиева, Т.К. Жукабаева, Ш. Тураев, М.А. Бердиева, Р.К. Сенгирбаева НАҚТЫ УАҚЫТ РЕЖИМІНДЕ МЕДИАРИРЕ ЖӘНЕ SVM АРҚЫЛЫ ҚАЗАҚ ҰМ ТІЛІН ТАҢУ.....	82
Ж.С. Иксебаева, К. Жетписов, А.Б. Медешова, И.М. Бапиев, Ж.Ж. Багисов ҒАЛЫМДАРДЫҢ ҒЫЛЫМИ ЖОБАЛАР БОЙЫНША ГРАНТТЫҚ ҚАРЖЫЛАНДЫРУҒА ҚАТЫСУҒА ӨТІНІМДЕРІН ДАЙЫНДАУДЫҢ АҚПАРАТТЫҚ ЖҮЙЕСІ.....	94
А.А. Иманберді, Р.Н. Молдашева ӘЛЕУМЕТТІК МЕДИА ТАРАТУ ҮЛГІЛЕРІНЕ ШОЛУ.....	107
Г. Қалман, М.Ғ. Есмағанбет, М.М. Жаманкарин, А.И. Габдулина, Д.В. Плескачев КЛАСТЕРЛЕУ ӘДІСІН ҚОЛДАНЫП КОРЕФЕРЕНЦИЯН ШЕШУ.....	121

Қ.Т. Қырғызбай, Е.Х. Какимжанов ГАЗ ТЕХНОЛОГИЯЛАРЫ НЕГІЗІНДЕ АЛМАТЫ ОБЛЫСЫНЫҢ ГЕОДЕРЕКТЕР БАЗАСЫН ҚҰРУ ВІТСОІН ЖЕЛІСІНДЕГІ КҮДІКТІ ТРАНЗАКЦИЯЛАРДЫ АНЫҚТАУ.....	136
Ш.Ж. Мусиралиева, М.Ж. Шайзат, А.К. Бекетова, Е. Абайұлы, А.Б. Манасова ВІТСОІН ЖЕЛІСІНДЕГІ КҮДІКТІ ТРАНЗАКЦИЯЛАРДЫ АНЫҚТАУ.....	154
А.Ұ. Мұхиядин, Ұ.Т. Махажанова, М.У. Мукашева, А.А. Муханова АҚПАРАТТЫҚ ТЕХНОЛОГИЯЛАР ТӨТЕНШЕ ЖАҒДАЙДА ҚАШЫҚТАН ОҚЫТУДА ЭКСПЕРИМЕНТТЫҚ ДЕРЕКТЕРДІ ТАЛДАУ ҚҰРАЛЫ РЕТІНДЕ.....	170
А.Б. Тоқтарова, Б.С. Омаров, Г.Н. Казбекова, С.А. Мамиков, Ф.Е. Темірбекова ӘЛЕУМЕТТІК ЖЕЛІДЕГІ ҚАЗАҚ ТІЛДІ БЕЙӘДЕП СӨЗДЕР ҚОРЫН МАШИНАЛЫҚ ОҚЫТУДА ЖИНАҚТАУ.....	191
А.Ә. Шекербек, Г.Б. Абдикеримова, Ж.Б. Ламашева, М.Г. Байбулова, А.К. Токкулиева ТЕРЕҢ ОҚЫТУ АЛГОРИТМІМЕН РЕНТГЕНДІК КЕСКІННІҢ КЛАССИФИКАЦИЯСЫ.....	204
Э.Э. Эльдарова JPEG2000 ҚЫСУЫНАН KEЙІН ЦИФРЛІК БЕЙНЕЛЕРДІҢ ВИЗУАЛДЫ САПАСЫН ЖАҚСАРТУ.....	228

СОДЕРЖАНИЕ

Ж.К. Абдугулова, Г.А. Ускенбаева, М.Н. Глеген, А.К. Шукирова АВТОМАТИЗАЦИЯ ТЕХНОЛОГИЧЕСКОГО ПРОЦЕССА ПОДОГРЕВА НЕФТИ НА ТРУБОПРОВОДНОМ ОБОРУДОВАНИИ.....	5
Ж.С. Авкурова, С.А. Гнатюк, Л.М. Кыдыралина, Н.К. Курмангалиева ИНТЕЛЛЕКТУАЛИЗИРОВАННЫЙ МЕТОД РАННЕГО ВЫЯВЛЕНИЯ ИДЕНТИФИКАЦИИ НАРУШИТЕЛЯ В ИНФОРМАЦИОННО-КОММУНИКАЦИОННЫХ СИСТЕМАХ.....	22
А. Бекарыстанқызы, О. Ж. Мамырбаев ИНТЕГРАЛЬНАЯ СИСТЕМА АВТОМАТИЧЕСКОГО РАСПОЗНАВАНИЯ СЛИТНОЙ РЕЧИ ДЛЯ АГГЛЮТИНАТИВНЫХ ЯЗЫКОВ.....	37
А.С. Еримбетова, Э.Н. Дайырбаева, Л. Черикбаева ВНЕДРЕНИЕ СКРЫТОЙ ИНФОРМАЦИИ В ИЗОБРАЖЕНИИ НА ОСНОВЕ БИКУБИЧЕСКОЙ ИНТЕРПОЛЯЦИИ.....	50
М.Б. Есенова, Г.Б. Абдикеримова, А. Толстой, Ж.Б. Ламашева, А.А. Некесова ПРИМЕНИМОСТЬ МЕТОДОВ АНАЛИЗА ТЕКСТУРНЫХ ИЗОБРАЖЕНИЙ ДЛЯ ВЫЯВЛЕНИЯ ОЧАГОВ СОРНЫХ ТРАВ ПШЕНИЦЫ.....	64
Л.З. Жолшиева, Т.К. Жукабаева, Ш. Тураев, М.А. Бердиева, Р.К. Сенгирбаева РАСПОЗНАВАНИЕ КАЗАХСКОГО ЖЕСТОВОГО ЯЗЫКА В РЕАЛЬНОМ ВРЕМЕНИ С ИСПОЛЬЗОВАНИЕМ MEDIAPIPE и SVM.....	82
Ж.С. Иксебаева, К. Жетписов, А.Б. Медешова, И.М. Бапиев, Ж.Ж. Багисов ИНФОРМАЦИОННАЯ СИСТЕМА ПОДГОТОВКИ ЗАЯВОК ДЛЯ УЧАСТИЯ В ГРАНТОВОМ ФИНАНСИРОВАНИИ УЧЕНЫХ ПО НАУЧНЫМ ПРОЕКТАМ.....	94
А.А. Иманберді, Р.Н. Молдашева ОБЗОР МОДЕЛЕЙ РАСПРОСТРАНЕНИЯ ИНФОРМАЦИИ В СОЦИАЛЬНЫХ СЕТЯХ.....	107

Г. Қалман, М.Ғ. Есмағанбет, М.М. Жаманқарин, А.Г. Габдулина, Д.В. Плескачев РЕШЕНИЕ КОРЕФЕРЕНЦИИ С ПОМОЩЬЮ МЕТОДА КЛАСТЕРИЗАЦИИ.....	121
Қ.Т. Қырғызбай, Е.Х. Какимжанов СОЗДАНИЕ БАЗЫ ГЕОДАНЫХ АЛМАТИНСКОЙ ОБЛАСТИ НА ОСНОВЕ ГИС-ТЕХНОЛОГИЙ О МЕТОДЕ ИДЕНТИФИКАЦИИ ПОДОЗРИТЕЛЬНЫХ ТРАНЗАКЦИЙ В БИТКОИН СЕТИ.....	136
Ш.Ж. Мусиралиева, М.Ж. Шайзат, А.К. Бекетова, Е. Абайұл, А.Б. Манасова О МЕТОДЕ ИДЕНТИФИКАЦИИ ПОДОЗРИТЕЛЬНЫХ ТРАНЗАКЦИЙ В БИТКОИН СЕТИ.....	154
А.Ұ. Мұхиядин, У.Т. Махажанова, М.У. Мукашева, А.А. Муханова ИНФОРМАЦИОННЫЕ ТЕХНОЛОГИИ КАК СРЕДСТВО АНАЛИЗА ЭКСПЕРИМЕНТАЛЬНЫХ ДАННЫХ ПРИ ЭКСТРЕННОМ ДИСТАНЦИОННОМ ОБУЧЕНИИ.....	170
А.Б. Токтарова, Б.С. Омаров, Г.Н. Казбекова, С.А. Мамиков, Ф.Е. Темирбекова СБОР БАЗЫ ДАННЫХ О ЯЗЫКЕ НЕНАВИСТИ В СОЦИАЛЬНОЙ СЕТИ НА КАЗАХСКОМ ЯЗЫКЕ С ИСПОЛЬЗОВАНИЕМ МАШИННОГО ОБУЧЕНИЯ.....	191
А.А. Шекербек, Г.Б. Абдикеримова, Ж.Б. Ламашева, М.Г. Байбулова, А.К. Токкулиева КЛАССИФИКАЦИЯ РЕНТГЕНОВСКИХ ИЗОБРАЖЕНИЙ С ПОМОЩЬЮ АЛГОРИТМА ГЛУБОКОГО ОБУЧЕНИЯ.....	204
Э.Э. Эльдарова УЛУЧШЕНИЕ ВИЗУАЛЬНОГО КАЧЕСТВА ЦИФРОВЫХ ИЗОБРАЖЕНИЙ ПОСЛЕ СЖАТИЕ JPEG2000.....	228

CONTENTS

J.K. Abdugulova, G.A. Uskenbayeva, M.N. Tlegen, A.K. Shukirova AUTOMATION OF THE TECHNOLOGICAL PROCESS OF HEATING OIL PIPELINE EQUIPMENT.....	5
Z. Avkurova, S. Gnatyuk, L. Kydyralina, N. Kurmangaliev THE INTELLECTUALIZED METHOD OF EARLY DETECTION AND IDENTIFICATION OF THE VIOLATOR IN INFORMATION AND COMMUNICATION SYSTEMS.....	22
A. Bekarystankyzy, O. Zh. Mamyrbayev INTEGRATED AUTOMATIC SPEECH RECOGNITION SYSTEM FOR AGGLUTINATIVE LANGUAGES.....	37
A. Yerimbetova, E. Daiyrbayeva, L. Cherikbayeva EMBEDDING HIDDEN INFORMATION IN IMAGES BASED ON BICUBIC INTERPOLATION.....	50
M. Yessenova, G. Abdikerimova, A. Tolstoy, Zh. Lamasheva, A. Nekessova APPLICABILITY OF TEXTURE IMAGE ANALYSIS METHODS FOR DETECTION OF WHEAT WEED POCKS.....	64
L. Zholshiyeva, T. Zhukabayeva, Sh. Turaev, M. Berdieva, R. Sengirbayeva REAL-TIME KAZAKH SIGN LANGUAGE RECOGNITION USING MEDIAPIPE AND SVM.....	82
Zh.S. Ixebayeva, K. Jetpisov, A.B. Medeshova, I.M. Bapiyev , Zh.Zh. Bagisov AN INFORMATION SYSTEM FOR THE PREPARATION OF APPLICATIONS FOR PARTICIPATION IN GRANT FUNDING OF SCIENTISTS IN SCIENTIFIC PROJECTS.....	94
A. Imanberdi, R. Moldasheva REVIEW OF MODELS OF DISSEMINATION OF INFORMATION IN SOCIAL NETWORKS.....	107
G. Kalman, M.G. Esmaganbet, M.M. Zhamankarin, A.I. Gabdulina, D.V. Pleskachev COREFERENCE SOLUTION USING THE CLUSTERING METHOD.....	121

K. Kyrgyzbay, E. Kakimzhanov CREATION OF A GEODATABASE OF ALMATY REGION BASED ON GIS TECHNOLOGIES.....	136
Sh. Mussiraliyeva, M. Shaizat, A. Beketova, Y. Abayuly, A. Manassova IDENTIFICATION OF SUSPICIOUS TRANSACTIONS IN THE BITCOIN NETWORK.....	154
A. Mukhiyadin, U. Makhazhanova, M. Mukasheva, A. Mukhanova INFORMATION TECHNOLOGIES AS A MEANS OF EXPERIMENTAL DATA ANALYSIS IN EMERGENCY DISTANCE LEARNING.....	170
A.B. Toktarova, B.S. Omarov, G.N. Kazbekova, S.A. Mamikov, F.E. Temirbekova COLLECTING HATE SPEECH DATABASE ON SOCIAL NETWORK IN KAZAKH LANGUAGE BY USING MACHINE LEARNING.....	191
A. Shekerbek, G. Abdikerimova, Zh. Lamasheva, M. Baibulova, A. Tokkuliyeva CLASSIFICATION OF X-RAY IMAGES USING THE DEEP LEARNING ALGORITHM.....	204
E.E. Eldarova IMPROVING THE VISUAL QUALITY OF DIGITAL IMAGES AFTER JPEG2000 COMPRESSION.....	228

**Publication Ethics and Publication Malpractice
the journals of the National Academy of Sciences of the Republic of Kazakhstan**

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 National Academy of Sciences of the Republic of Kazakhstan 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 National Academy of Sciences of the Republic of Kazakhstan 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 National Academy of Sciences of the Republic of Kazakhstan.

The Editorial Board of the National Academy of Sciences of the Republic of Kazakhstan will monitor and safeguard publishing ethics.

Правила оформления статьи для публикации в журнале смотреть на сайтах:

www.nauka-nanrk.kz

<http://physics-mathematics.kz/index.php/en/archive>

ISSN 2518-1726 (Online),

ISSN 1991-346X (Print)

Заместитель директора отдела издания научных журналов НАН РК *Р. Жалиқызы*

Редакторы: *М.С. Ахметова, Д.С. Аленов*

Верстка на компьютере *Г.Д. Жадыранова*

Подписано в печать 30.03.2023.

Формат 60x881/8. Бумага офсетная. Печать – ризограф.

15,5 п.л. Тираж 300. Заказ 1.