International Journal of Electrical and Computer Engineering (IJECE)
Vol. 13, No. 5, October 2023, pp. 5569~5575
ISSN: 2088-8708, DOI: 10.11591/ijece.v13i5.pp5569-5575

Applying textural Law's masks to images using machine learning

Gulzira Abdikerimova[1], Moldir Yessenova[1], Akbota Yerzhanova[2], Zhanat Manbetova[3], Gulden Murzabekova[4], Dinara Kaibassova[5], Roza Bekbayeva[6], Madina Aldashova[1]

[1]Department of Information Systems, Faculty of Information Technology, L. N. Gumilyov Eurasian National University, Astana, Republic of Kazakhstan
[2]Department of Technological Machines and Equipment, Faculty of Technology, S. Seifullin Kazakh Agrotechnical University, Astana, Republic of Kazakhstan
[3]Department of Radio Engineering, Electronics and Telecommunications, Faculty of Energy, Saken Seifullin Kazakh Agrotechnical University, Astana, Republic of Kazakhstan
[4]Department of Computer Sciences, Faculty of Information Technology, S. Seifullin Kazakh Agrotechnical University, Astana, Republic of Kazakhstan
[5]Department of Information and Computing Systems, Non-Profit Limited Company Abylkas Saginov Karaganda State University, Karaganda, Republic of Kazakhstan
[6]Department of Automation, Information Technology and Urban Development of Non-Profit Limited Company Semey University named after Shakarim, Semey, Republic of Kazakhstan

Article Info

Article history:

Received Mar 1, 2023
Revised Apr 25, 2023
Accepted Apr 27, 2023

Keywords:

Image processing
k-means
Law's textural masks
Machine learning
Texture analysis
Weeds

ABSTRACT

Currently, artificial neural networks are experiencing a rebirth, which is primarily due to the increase in the computing power of modern computers and the emergence of very large training data sets available in global networks. The article considers Laws texture masks as weights for a machine-learning algorithm for clustering aerospace images. The use of Laws texture masks in machine learning can help in the analysis of the textural characteristics of objects in the image, which are further identified as pockets of weeds. When solving problems in applied areas, in particular in the field of agriculture, there are often problems associated with small sample sizes of images obtained from aerospace and unmanned aerial vehicles and insufficient quality of the source material for training. This determines the relevance of research and development of new methods and algorithms for classifying crop damage. The purpose of the work is to use the method of texture masks of Laws in machine learning for automated processing of high-resolution images in the case of small samples using the example of problems of segmentation and classification of the nature of damage to crops.

Corresponding Author:

Moldir Yessenova
Department of Information Systems, Faculty Information Technology, L. N. Gumilyov Eurasian National University
010000 Astana, Republic of Kazakhstan
Email: moldir_11.92@mail.ru

1. INTRODUCTION

In the context of the globalization of economic mechanisms in agriculture, the role of food programs is increasing, aimed at solving the problems of providing the population with food, light, and food industries - with raw materials. In developed countries, commercial agriculture predominates, while traditional forms of agriculture are represented mainly in developing countries. One of the main objectives of the program and plan is the development of the National Agriculture of the Republic of Kazakhstan, increasing the productivity, quality, and sustainability of agricultural products using modern technologies. The successful solution to such a problem requires automated image processing [1]–[4] for agricultural management, which can become a tool for displaying the state and structure of agricultural production and the results of the agricultural inventory. In addition, data reflecting the composition, structure, and state of agriculture in digital form are insufficiently presented. The solution to this problem requires the development of a modern scientific-practical basis for the optimal compilation and prompt updating of digital data on the state of agricultural fields, as well as the creation of updated databases in the interests of agricultural management. In this regard, the developed machine learning methods make it possible to improve numerical indicators when processing images of high spatial resolution on the example of segmentation [5], [6], classification [7], [8], and categorization [9], [10] problems of the nature of vegetation damage. Also, in the future, they can be used in the monitoring system of forestry and agriculture using unmanned aerial vehicles (UAVs). To solve the problems posed in the work, methods of remote sensing data preprocessing, the Laws texture mask method [11] as weights in machine learning, and the clustering method (k-means) were used.

Puri *et al*. [12] characterized various types of leaves of medicinal plants using a computer classification system. The classification system used by the authors mainly distinguishes between the texture features of various leaves of medicinal plants. To achieve the desired result, the researchers took five classes of different types of plant leaves and extracted their textural features using Loves texture masks, and the support vector machine (SVM) classifier is used for the classification task. In this work, the authors did not consider machine learning methods that make distinguishing between plant leaf types possible.

Yessenova *et al.* [13] presented an analysis of a non-standard approach to the segmentation of texture regions in aerospace images. The question of the applicability of sets of textural features for the analysis of experimental data to identify characteristic areas in aerospace images, which in the future can be used to identify types of crops, weeds, diseases, and pests, is being investigated. Suitable algorithms were selected and appropriate software tools were created, but machine-learning methods for automated image processing were not considered.

Syed and Suganthi [14] proposed a strategy in which weeds are characterized by a set of shape descriptors. Weeds appear in pictures of an open-air field, which reflect real situations taken from the red, green and blue (RGB) camera. In the approach presented by the authors, four decision methods were adapted to use the best form descriptors as attributes, and a choice was made. The authors did not consider machine learning methods for automated image processing to identify weeds in agriculture.

A review of the results of an experiment on the combined use of spectral and structural features for the classification of vegetation on hyperspectral aerial photographs [15]. The information content of the texture properties displayed in the ENVI package was analyzed in different parts of the spectrum from 400 to 1,000 nm. An example is given where the combined use of spectral and textural features improves the classification accuracy. In this work, the analysis of multispectral images and spectrophotometric coefficients was not carried out. Martinez *et al*. [16] identified flax and weed patches as structural features in aerial photographs. According to scientific literature, each task definition does not have a unique texture information vector. Also, the article does not specifically mention wheat and did not find any factors negatively affecting its growth. A distinctive feature of this work is the recognition of objects in aerial photographs by their structural features. That is, by analyzing experimental data, we explored the possibility of using sets of texture features to highlight characteristic areas in aerial photographs.

2. METHOD

In this work, we used the texture search method based on the comparison of the Laws energy characteristics for the sample and the processed image. In a software implementation experiment, Laws texture masks were used as weights in machine learning [17], [18] to find uniform textures in images. The proposed algorithm for calculating texture features is invariant to scale changes Figure 1. The main idea of the algorithm is to calculate energy texture features using local masks at each level. 25 local masks are obtained by pairwise multiplication of one-dimensional vectors L5, E5, S5, W5, and R5 proposed by K. Laws [19]–[21]. Base vectors allow you to calculate a symmetrical weighted local average, and detect edges, spots, waves, and ripples as in (1).

L5 = [1 4 6 4 1] - Level - average grey level
E5 = [-1 -2 0 2 1] - Edge - extract edge features
S5 = [-1 0 2 0 -1] - Spot - extract spots
R5 = [1 -4 6 -4 1] - Ripple - extract ripples
W5 = [-1 2 0 -2 1] - Wave - extract wave features (1)

The normalized values of each resulting local matrix were used as weights in machine learning. The Loves texture mask method highlights homogeneous regions in images with stochastic texture regions. The comparative high accuracy of the result of the method of 25 possible texture masks was estimated by the method of the average standard deviation [22]–[24].

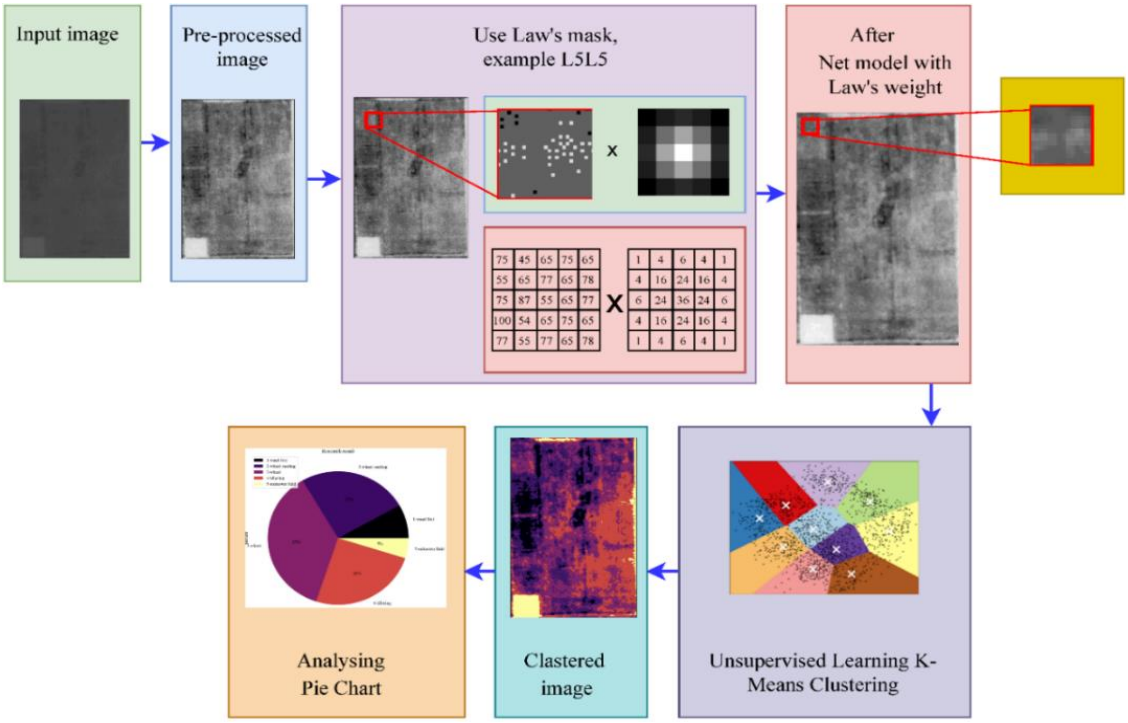

Figure 1. The architecture of automated image processing using Loves texture masks

3. RESULTS AND DISCUSSION

In this work, the reviewed original image was requested from the Planet.com server, which was made from publicly available satellite images of Sentinel-2. Despite the high resolution of the obtained aerial photographs, it is difficult to distinguish homogeneous areas in Figure 2. Therefore, taking into account the effectiveness of the texture masks used in [25], image preprocessing was automated.

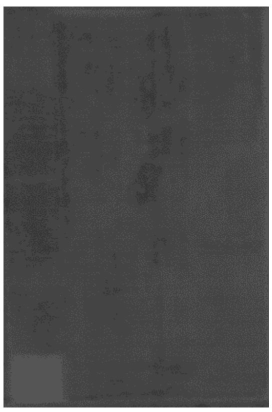

Figure 2. The original image of the selected field

The matrix obtained as the current 5*5 texture mask is multiplied by the corresponding element of the original image and summed up. The result obtained is placed in the center of the considered current part of the matrix. Thus, a new matrix is created by traversing the entire matrix of the current window. Figure 3 shows the average value of the considered possible 25 texture masks.

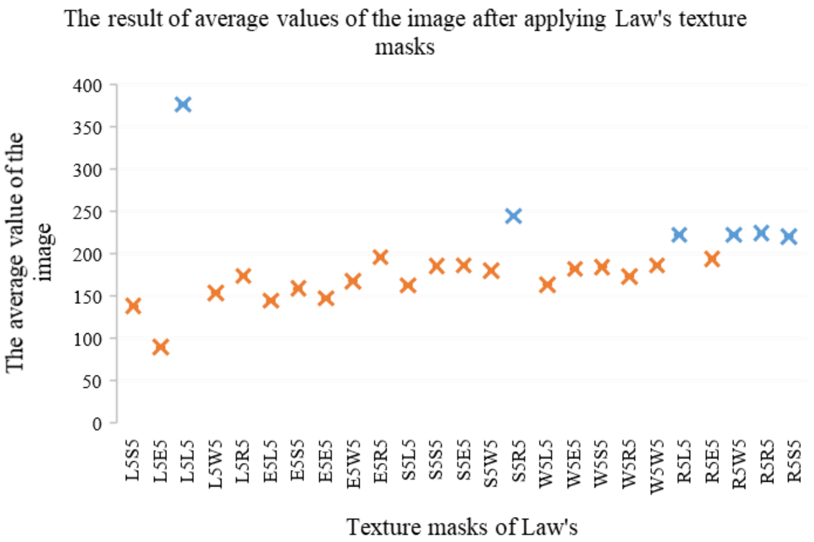

Figure 3. Result of average values after applying texture masks

When comparing the values obtained after the standard deviation, the six texture mask values scored higher. Based on the result obtained, according to the values of 6 images, their resulting images are shown in Figure 4, i.e., the original image in Figure 4(a), the result of applying the texture mask is L5L5=375.63 in Figure 4(b), the result of applying the texture mask is S5R5=244.63 in Figure 4(c), the result of applying the texture mask is R5L5=221.8 in Figure 4(d), the result of applying the texture mask is R5W5= 1.8 in Figure 4(e), the result of applying the texture mask is R5R5=223.97 in Figure 4(f). As a result, obtained from the L5L5 texture mask at the maximum value, homogeneous areas were well highlighted.

After applying textural masks to the resulting images, the k-means clustering method was applied. The results of the experiment are shown in Figure 5. In the field under consideration, the number of clusters was 5. That is weed foci, unsown fields, wheat seedlings, tillering, and wheat.

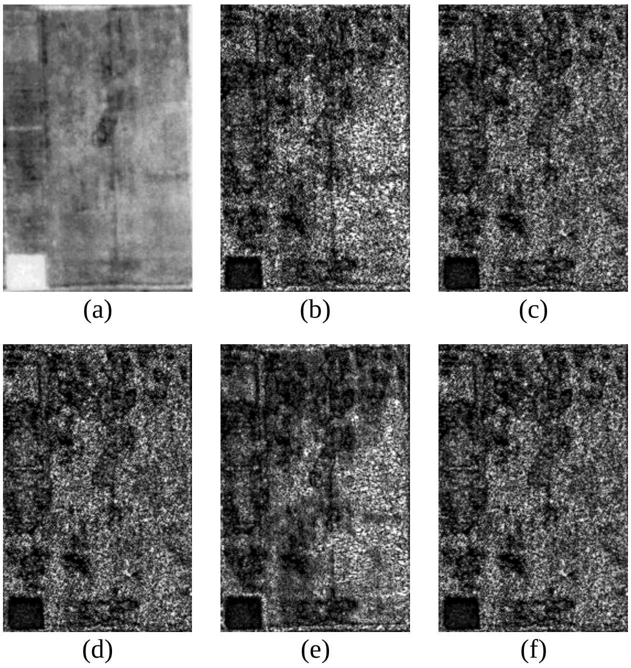

Figure 4. The result of applying 6 textural masks: (a) original image, (b) the result of applying the textural mask – L5L5=375.63, (c) the result of applying the textural mask – S5R5=244.63, (d) the result of applying the textural mask – R5L5= 221.8, (e) the result of applying the textural mask – R5W5=221.8, and (f) the result of applying the textural mask – R5R5=223.97

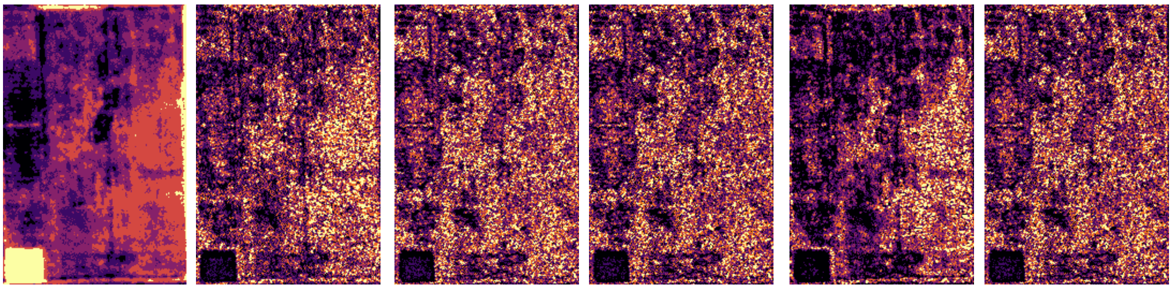

Figure 5. Result after applying k-means clustering

Due to the limited availability of satellite images, i.e., due to the presence of clouds or technical interference during the required growing season, the amount of data required is small. Therefore, the machine learning method was used for the automatic processing of space images. The texture mask L5L5 was solved informatively from images obtained from the results of the texture energy masking method used as weights in machine learning. The matrix size of this mask is inserted as a weight into the automatic image processing system.

4. CONCLUSION

As a result of the research performed in this work, the tasks were solved, and the main goal of the work was achieved–the use of the Laws texture mask method in machine learning for automated image processing to classify the nature of crop damage. An algorithm for the selection of homogeneous regions in images with a high spatial resolution under conditions of small samples has been developed. The normalized values of Loves texture masks as weights to the original image in machine learning were calculated. The results of 25 possible texture mask values were evaluated using the standard deviation. As a result of the deviation, 6 texture masks were selected: L5L5, S5R5, R5L5, R5W5, and R5R5. After applying the k-means clustering method to all six images, homogeneous areas were clearly visible in the images. But the maximum accuracy was determined by the result of applying the L5L5 texture mask, which is more informative among the selected masks. The developed algorithm is the basis for creating libraries that can be used as part of software systems for solving a wide range of digital image processing and pattern recognition problems.

REFERENCES

[1] A. Caggiano, J. Zhang, V. Alfieri, F. Caiazzo, R. Gao, and R. Teti, “Machine learning-based image processing for on-line defect recognition in additive manufacturing,” *CIRP Annals*, vol. 68, no. 1, pp. 451–454, 2019, doi: 10.1016/j.cirp.2019.03.021.

[2] R. B. Hegde, K. Prasad, H. Hebbar, and B. M. K. Singh, “Comparison of traditional image processing and deep learning approaches for classification of white blood cells in peripheral blood smear images,” *Biocybernetics and Biomedical Engineering*, vol. 39, no. 2, pp. 382–392, Apr. 2019, doi: 10.1016/j.bbe.2019.01.005.

[3] L. C. Ngugi, M. Abelwahab, and M. Abo-Zahhad, “Recent advances in image processing techniques for automated leaf pest and disease recognition - a review,” *Information Processing in Agriculture*, vol. 8, no. 1, pp. 27–51, Mar. 2021, doi: 10.1016/j.inpa.2020.04.004.

[4] H. Tian, T. Wang, Y. Liu, X. Qiao, and Y. Li, “Computer vision technology in agricultural automation - a review,” *Information Processing in Agriculture*, vol. 7, no. 1, pp. 1–19, Mar. 2020, doi: 10.1016/j.inpa.2019.09.006.

[5] S. Hao, Y. Zhou, and Y. Guo, “A brief survey on semantic segmentation with deep learning,” *Neurocomputing*, vol. 406, pp. 302–321, Sep. 2020, doi: 10.1016/j.neucom.2019.11.118.

[6] X. Liu, L. Song, S. Liu, and Y. Zhang, “A review of deep-learning-based medical image segmentation methods,” *Sustainability*, vol. 13, no. 3, Jan. 2021, doi: 10.3390/su13031224.

[7] G. Cheng, X. Xie, J. Han, L. Guo, and G.-S. Xia, “Remote sensing image scene classification meets deep learning: challenges, methods, benchmarks, and opportunities,” *IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing*, vol. 13, pp. 3735–3756, 2020, doi: 10.1109/JSTARS.2020.3005403.

[8] L. Armi and S. Fekri-Ershad, “Texture image analysis and texture classification methods - a review,” *Prepr. arXiv.1904.06554*, Apr. 2019.

[9] S. Kailasam, S. D. M. Achanta, P. R. K. Rao, R. Vatambeti, and S. Kayam, “An IoT-based agriculture maintenance using pervasive computing with machine learning technique,” *International Journal of Intelligent Computing and Cybernetics*, vol. 15, no. 2, pp. 184–197, Apr. 2022, doi: 10.1108/IJICC-06-2021-0101.

[10] A. Ahmed, A. Jalal, and K. Kim, “A novel statistical method for scene classification based on multi-object categorization and logistic rregression,” *Sensors*, vol. 20, no. 14, Jul. 2020, doi: 10.3390/s20143871.

[11] M. Yessenova *et al.*, “The effectiveness of methods and algorithms for detecting and isolating factors that negatively affect the growth of crops,” *International Journal of Electrical and Computer Engineering (IJECE)*, vol. 13, no. 2, pp. 1669–1679, Apr. 2023, doi: 10.11591/ijece.v13i2.pp1669-1679.

[12] D. Puri, A. Kumar, J. Virmani, and Kriti, “Classification of leaves of medicinal plants using law's texture features,” *International Journal of Information Technology*, vol. 14, no. 2, pp. 931–942, Mar. 2022, doi: 10.1007/s41870-019-00353-3.

[13] M. Yessenova *et al.*, "Application of informative textural Law's masks methods for processing space images," *International Journal of Electrical and Computer Engineering (IJECE)*, vol. 13, no. 4, pp. 4557–4566, Aug. 2023, doi: 10.11591/ijece.v13i4.pp4557-4566.
[14] Z. Syed and K. Suganthi, "Crop and weed semantic segmentation using a fuzzy transform based active contour model," in *2023 International Conference on Innovative Data Communication Technologies and Application (ICIDCA)*, Mar. 2023, pp. 587–591. doi: 10.1109/ICIDCA56705.2023.10099979.
[15] M. A. Hassan *et al.*, "A rapid monitoring of NDVI across the wheat growth cycle for grain yield prediction using a multi-spectral UAV platform," *Plant Science*, vol. 282, pp. 95–103, May 2019, doi: 10.1016/j.plantsci.2018.10.022.
[16] P. Martinez, M. Al-Hussein, and R. Ahmad, "A scientometric analysis and critical review of computer vision applications for construction," *Automation in Construction*, vol. 107, Nov. 2019, doi: 10.1016/j.autcon.2019.102947.
[17] G. Nguyen *et al.*, "Machine learning and deep learning frameworks and libraries for large-scale data mining: a survey," *Artificial Intelligence Review*, vol. 52, no. 1, pp. 77–124, Jun. 2019, doi: 10.1007/s10462-018-09679-z.
[18] C. A. Ramezan, T. A. Warner, and A. E. Maxwell, "Evaluation of sampling and cross-validation tuning strategies for regional-scale machine learning classification," *Remote Sensing*, vol. 11, no. 2, Jan. 2019, doi: 10.3390/rs11020185.
[19] R. Kamath, M. Balachandra, and S. Prabhu, "Crop and weed discrimination using Laws' texture masks," *International Journal of Agricultural and Biological Engineering*, vol. 13, no. 1, pp. 191–197, 2020, doi: 10.25165/j.ijabe.20201301.4920.
[20] S. Dash and M. R. Senapati, "Noise robust laws' filters based on fuzzy filters for texture classification," *Egyptian Informatics Journal*, vol. 21, no. 1, pp. 37–49, Mar. 2020, doi: 10.1016/j.eij.2019.10.003.
[21] W. Zhang, Z. Miao, N. Li, C. He, and T. Sun, "Review of current robotic approaches for precision weed management," *Current Robotics Reports*, vol. 3, no. 3, pp. 139–151, Jul. 2022, doi: 10.1007/s43154-022-00086-5.
[22] S. McGrath *et al.*, "Estimating the sample mean and standard deviation from commonly reported quantiles in meta-analysis," *Statistical Methods in Medical Research*, vol. 29, no. 9, pp. 2520–2537, Sep. 2020, doi: 10.1177/0962280219889080.
[23] M. Song and L. Cheng, "A generalized benders decomposition approach for the mean-standard deviation shortest path problem," *Transportation Letters*, pp. 1–11, Jun. 2022, doi: 10.1080/19427867.2022.2092045.
[24] Y. Zhao, Q. Wu, P. Wei, H. Zhao, X. Zhang, and C. Pang, "Explore the mitigation mechanism of urban thermal environment by integrating geographic detector and standard deviation ellipse (SDE)," *Remote Sensing*, vol. 14, no. 14, Jul. 2022, doi: 10.3390/rs14143411.
[25] M. Yessenova *et al.*, "Identification of factors that negatively affect the growth of agricultural crops by methods of orthogonal transformations," *Eastern-European Journal of Enterprise Technologies*, vol. 3, no. 2 (117), pp. 39–47, Jun. 2022, doi: 10.15587/1729-4061.2022.257431.

BIOGRAPHIES OF AUTHORS

Gulzira Abdikerimova received her Ph.D. in 2020 in Information Systems from L.N. Gumilyov Eurasian National University, Kazakhstan. Currently, she is an associate professor at the Department of Information Systems at the same university. Her research interests include image processing, computer vision, satellite imagery, artificial intelligence, and machine learning. You can contact her at gulzira1981@mail.com.

Moldir Yessenova received a bachelor's degree in information systems in 2014 and a master's degree in 2017 in information technology from L.N. Gumilyov Eurasian National University, Kazakhstan, Nursultan. Currently, she is a doctoral student at the Department of Information Systems at the L.N. Gumilyov Eurasian National University. Her research interests include image processing, computer vision, satellite imagery, artificial intelligence, and machine learning. You can contact her at moldir_11.92@mail.ru.

Akbota Yerzhanova defended her Doctor of Philosophy (Ph.D.) in the specialty 6D070300 - "Information Systems" at the L.N. Gumilyov Eurasian National University in Astana. Currently, she works at the Kazakh Agrotechnical University named after S. Seifullin. She is the author or co-author of more than 15 publications. The Hirsch index is 2. Her research interests include geoinformation technologies, pattern recognition, and artificial intelligence. You can contact her at erjanova_akbota@mail.ru.

Zhanat Manbetova In 1999, she graduated from the Korkyt-Ata Kyzylorda State University with a degree in Physics and Additional Mathematics. In 2014, she graduated with a master's degree in "Radio Engineering, Electronics and Telecommunications" from Kazakh Agrotechnical University named after S. Seifullin. In 2022, she defended her doctoral dissertation in the specialty "Radio engineering, electronics and telecommunications". From 2021 to the present, he is a Doctor of Philosophy PhD of the Department of "Radio Engineering, Electronics and Telecommunications" of the Kazakh Agrotechnical University named after S. Seifullin. She is the author of more than 40 works. His research interests include wireless communications, mobile communication systems, GSM, and mobile systems management, as well as mobile communication technologies. She can be contacted at zmanbetova@inbox.ru.

Gulden Murzabekova graduated from the Faculty of Applied Mathematics-Control Processes of Saint-Petersburg State University in 1994, where she also successfully defended her doctoral thesis in 1997 on discrete mathematics and mathematical cybernetics. Since 1998, she has been an associate professor in the Department of Informatics, head of the Information and Communication Technologies Department during 2003-2022, and recently she is an associate professor of the Computer Science Department at Seifullin Kazakh Agrotechnical University. She has authored more than 100 papers. Her research interests include numerical methods of nonsmooth analysis and nondifferentiable optimization, mathematical modeling, artificial intelligence, and machine learning. She can be contacted at email g.murzabekova@kazatu.kz.

Dinara Kaibassova graduated from Almaty State University named after Abay with a degree in Informatica in 1999. In 2020, she defended her dissertation in the specialty "6D070300 - Informations systems" and received a Ph.D. She began her career in 2000 as an assistant at the Department of Applied Mathematics and Computer Science of Zhezkazgan Baikonurov University. Currently, she is an Acting Associate Professor at the Department of Information and Computing Systems of Non-profit limited company Abylkas Saginov Karaganda State University. She is the author of more than 70 scientific papers, including 2 monographs and 4 articles in the Scopus database. Scientific interests - image processing, pattern recognition theory, data mining, natural language processing. She can be contacted at dindgin@mail.ru.

Roza Bekbayeva graduated from the Semipalatinsk State University named after Shakarim with a degree in Automation of Technological Processes in 2000. In 2010 she defended her dissertation in the specialty "05.18.12 - Processes and apparatuses of food production" and received a Ph.D. She began her career in 2001 as an assistant at the Department of Automation and Control of SSU named after Shakarim. Currently, she is an Acting Associate Professor at the Department of Automation, Information Technology and Urban Development of Non-profit limited company Semey University named after Shakarim. She is the author of more than 60 scientific papers, including 1 monograph, 3 provisional patents of the Republic of Kazakhstan for an invention, and 2 articles in the Scopus database. Scientific interests-modeling in the field of engineering and technology for the development of products based on renewable systems. She can be contacted at roza.toghan3194@gmail.com.

Madina Aldashova received a bachelor's degree in mathematics and computer science in 2002 and a master's degree in the field of information systems in 2013 from the University of Turan-Astana, Kazakhstan, Nursultan. Currently, she is studying doctoral studies at the Department of Information Systems of the Institute named after L.N. Gumilyov at Eurasian National University. Her research interests include mathematical modeling, computer technology, models, and control methods, biosystems, and control systems. You can contact her at maldashova@internet.ru.