Application of informative textural Law's masks methods for processing space images

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ABSTRACT

Image processing systems are currently used to solve many applied problems. The article is devoted to the identification of negative factors affecting the growth of grain in different periods of harvesting, using a program implemented in the MATLAB software environment, based on aerial photographs. The program is based on the Law's textural mask method and successive clustering. This paper presents the algorithm of the program and shows the results of image processing by highlighting the uniformity of the image. To solve the problem, the spectral luminance coefficient (SBC), normalized difference vegetation index (NDVI), Law's textural mask method, and clustering are used. This approach is general and has great potential for identifying objects and territories with different boundary properties on controlled aerial photographs using groups of images of the same surface taken at different vegetation periods. That is, the applicability of sets of Laws texture masks with original image enhancement for the analysis of experimental data on the identification of pest outbreaks is being investigated.

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1. INTRODUCTION

One of the tasks put forward within the framework of the development program of the National Agricultural Union of the Republic of Kazakhstan is to improve the quality of public services and ensure the introduction of digital technologies in the agro-industrial complex. complex, which is associated with the development of video filming technologies in various fields, their automatic recognition is based on mathematical algorithms. At present, the problem of creating algorithms that separate images from different sources into clusters often arises in such applied areas as, for example, the analysis of photographs of the earth's surface, and the detection of defects and cracks in images. In addition, depending on research reports video processing methods, for example, highlighting the most informative fragments and increasing them, increasing the intensity contrast, and improving image quality. Therefore, studying textural features, and extracting information from them, such as distinguishing crop varieties and identifying factors that negatively affect their growth, digitization of data remains a hot topic [1]. This study is based on the characteristics of crop growth during the growing season and factors that adversely affect the growth of crops in the Research and Production Center for Grain Farming named after, A.I. Barayev.

This article discusses a method for detecting weed foci from surface images using a program implemented in the MATLAB software environment. As the main methods for determining the texture properties of images, one can distinguish the statistical characteristics of the first and second orders, the Loves texture map method, the orthogonal transformation method, and the autocorrelation function method. When developing this program, it was customary to use the Lowe texture map method, since this method determines for each pixel a set of attributes by which image segmentation can be performed, and this method also has some advantages in terms of calculation time, for example, compared to the method statistical characteristics of the second order and structural characteristics [2]. It is assumed that each of them can be additionally associated with properties of texture characteristics, such as the ratio of order/disorder, the ratio of "anomalous" regions of the texture, as well as various spectral coefficients. It has the value of representing weeds, plants, and crops. The results obtained are used in scientific research, in particular, in the A.I. Barayev Research and Production Center for Grain Farming, as a control of factors that negatively affect the yield, by analyzing multi-spectral images. Namely, the use of chemical fertilizers in areas affected by weeds makes it possible to reduce the cost of losses, and in some cases preserve the natural fertility of the soil cover [3].

In the future, using the most effective of the mentioned methods in machine learning, an automated application will be developed that will develop a system of actions to optimize various resources, increase productivity, and eliminate factors that negatively affect high performance without harming the environment. For a more complete characterization of the issue under consideration, the works of several authors were studied. Tang *et al.* [4] solved the problem of unstable detection results and poor generalization based on feature extraction from manual features in weed detection. Soybean seedlings and related weeds were considered an object of study, and a weed identification model was built based on the study of K-means features in combination with a convolutional neural network. Jin *et al.* [5] proposed a new method that combines deep learning and image processing technology to detect vegetables and draw bounding boxes around them. Subsequently, the remaining green objects falling out of the bounding boxes were treated as weeds. To isolate weeds from the background, color index-based segmentation was performed using image processing. The color index used was determined and evaluated using genetic algorithms (GAS) according to the Bayesian classification error.

Peteinatos *et al.* [6] reviewed images collected with an RGB camera *Zea mays, Helianthus annuus, Solanum tuberosum, Alopecurus myosuroides Amaranthus retroflexus, Avena fatua, Chenopodium album, Lamium purpureum22, Matricaria chamomilla, Setaria spp., Solanum nigrum*, and *Stellaria media*; and have been provided for training convolutional neural networks (CNNS). Three different CNNs, namely VGG16, ResNet-50, and Xception, were adapted and trained on a pool of 93,000 images. The training images consisted of plant material images containing only one species per image. Peteinatos *et al.* [6] have proposed a method for improving problems relating to the speed, reliability, and accuracy of recognition algorithms and systems and artificial neural networks (ANNs). The image testing yielded Top-1 accuracy ranging from 77% to 98% in plant detection and weed species discrimination. Sabzi *et al.* [7] presents a new computer vision-based expert system for identifying potato plants and three different weed species (*Secale cereale L.*, *Polygonum aviculare L.*, and *Xanthium strumarium L.*) for spraying a specific area. The main contribution of the proposed approach was the application of two metaheuristic algorithms to optimize the performance of the neural network classifier: first, the cultural algorithm is used to select the five most effective features to increase the efficiency of calculations; then a harmonious search algorithm is applied to find the optimal network configuration. Ağın and Taner [8] determined the density of broadleaf weeds and contributed to the reduction of herbicide use in wheat fields. To this end, the authors used image processing techniques and also developed artificial neural networks and regression models to identify weeds. In [9], the spectral transformation was applied to several orthonormal image bases obtained using electron microscopy. The efficiency and speed of technological processes, porosity, and diffusion coefficient. demonstrated the effectiveness of determining the degree of damage to plant cell walls from microphotographs. In this paper, methods based on orthogonal bases were performed on electron microscope images, and the effectiveness of aerospace images was not demonstrated.

The results of experiments [10] on the joint use of spectral and textural features for the classification of vegetation cover on aviation hyperspectral images are considered. The information content of textural features offered in the ENVI package is analyzed in different parts of the spectrum in the range of 400–1,000 nm. Examples are given in which the combined use of spectral and textural features makes it possible to increase classification accuracy. In this work, the analysis of multispectral images and spectral brightness coefficients was not carried out. In the article [11], the authors identified flax and weed patches as structural features in the aeronautical images. According to the scientific literature, there is no exact texture feature information vector for every problem definition. And this article is not specifically about wheat, and no factors have been identified that negatively affect its growth. A feature of this work is the detection of objects in aviation images based on texture features. That is, we investigate the applicability of texture feature sets to identify feature regions in aerial imagery by analyzing experimental data.

2. METHODS

This research work was carried out on a land plot owned by the Research Institute A.I. Barayev at the cadastral number 01-012-025-040:42. Information about the received aerospace images for each growing season was identified with the data of the experts of this research center. One of the methods used in the course of the study was the textural Laws mask. Due to the presence of different textures in aerospace images, the textural masks created by Laws showed their structural difference. The main idea on which Laws' method of texture characteristics is based is to estimate the change in texture content within a fixed-size window [12]. To calculate the energy characteristics, a set of 25 masks sized 5×5 is used. When compiling Laws masks, 5 vectors are used (1):

$$\begin{aligned} &L5 = [1\ 4\ 6\ 4\ 1]\ -\ Level\ -\ average\ grey\ level \\ &E5 = [-1\ \ -2\ 0\ 2\ 1]\ -\ Edge\ -\ extract\ edge\ features \\ &S5 = [-1\ 0\ 2\ 0\ 2\ \ -1]\ -\ Spot\ -\ extract\ spots \\ &R5 = [1\ \ -4\ 6\ \ -4\ 1]\ -\ Ripple\ -\ extract\ ripples \\ &W5 = [-1\ 2\ 0\ \ -2\ 1]\ -\ Wave\ -\ extract\ wave\ features \end{aligned} \tag{1}$$

The next step is the averaging procedure, which combines symmetrical pairs of masks. Now, multiplying these vectors with each other, we got twenty-five different masks as shown in Table 1.

Table 1. Combines symmetrical pairs of masks

Possible 5×5 Laws' masks				
L5L5	E5L5	S5L5	W5L5	R5L5
L5E5	E5E5	S5E5	W5E5	R5E5
L5S5	E5S5	S5S5	W5S5	R5S5
L5W5	E5W5	S5W5	W5W5	R5W5
L5R5	E5R5	S5R5	W5R5	R5R5

Given a sample image with N rows and M columns for which we want to perform texture analysis, we first apply each of our chosen convolution kernels to the image. The result is a set of grayscale images, each of dimensions $N - window\ size + 1 \times M - window\ size + 1$, where the window size was chosen to be 5. These convolution results will form the basis of our textural analysis.

The next step is to perform a windowing operation (marquee window size 5×5), where we replace each pixel in the images obtained after different sizes around each pixel, and count the following three descriptors:

– Averaging the absolute values of the neighborhood pixels.

$$\mu = \frac{\sum_N (\text{neighbouring\_pixels})}{N} \tag{1}$$

– Averaging the values of the neighborhood pixels.

$$\sigma = \frac{\sum_N abs(\text{neighbouring\_pixels})}{N} \tag{2}$$

– Calculating standard deviation for the neighborhood pixels.

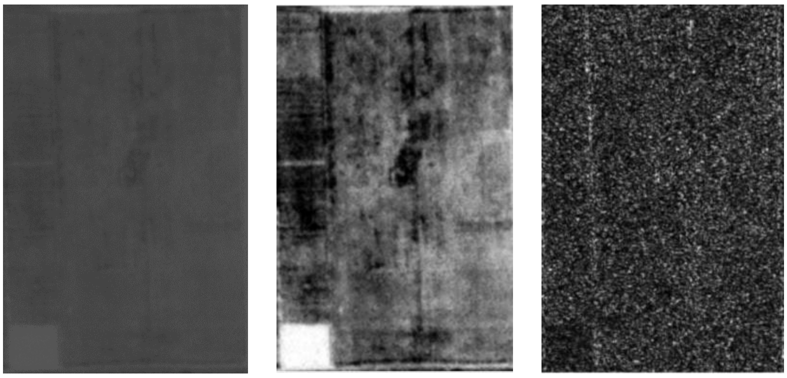
$$abs\_\mu = \sqrt{\frac{\sum_N (\text{neighbouring\_pixels} - \mu)^2}{N}} \tag{3}$$

To test the information content of texture masks, Laws were compared with methods applied to places belonging to the A.I. Barayev Research Institute. The article [9] shows methods of orthogonal transformation for distinguishing between agricultural cereals and their weeds. This paper presents 6 methods of orthogonal transformation: Cosine [13], [14]; Hadamard order 2^n [15], [16]; Hadamard order $n = p + 1$, $p \equiv 3(mod\ 4)$ – a prime number, i.e. based on the Legendre symbol [17]; Haar [18], [19]; Slant [20], [21]; and Dobeshi -4 [22], [23].

3. RESULT AND DISCUSSION

3.1. Analysis of Law's texture mask method

A texture mask is a traditional method for obtaining texture marks, the main method of which is to filter images using five types of masks, namely levels, edges, spots, ripples, waves. Each combination of these masks provides unique information. This article used image processing i.e., improving image quality and using low-texture masks on the original image. 25 texture masks 5×5 was tested on images from different stages of vegetation. For example, Figure 1 shows a piece of land where calculations were carried out, in Figure 1(a) shows an indexed original image of the field in question where wheat was grown. Figure 1(b) shows the result of applying the L5L5 mask. Figure 1(c) shows the result of applying the L5S5 mask. According to the standard approach, the size of the working window was 5×5, and the texture mask of the Law was applied to each window. In this step of image processing, we create a new set of images called texture energy measurement (TEM) images.



(a) (b) (c)

Figure 1. A piece of land where calculations were carried out: (a) the original image of the taken field, (b) the result of clustering using the texture mask Laws L5L5, and (c) the result of clustering using the texture mask Laws L5S5

The next step is that all images obtained after working with windows should be normalized to display well as an image. All possible combinations are allowed for use 25, of which 5×5 for masks as shown in Table 1. After reading and converting the image to grayscale, the MATLAB function is used to process the convolution, taking the image matrix and the filter kernel matrix as an argument. The next step in developing the function is to calculate the window statistics given the neighborhood of the pixel. A statistical descriptor can be (1) the mean, (2) the mean of the absolute values or (3) the standard deviation, so depending on the input string (string statistic type) we can calculate each.

Multispectral analysis of images was carried out in the ENVI environment, that is, the spectral brightness coefficient in each growing season has a different information value [24]. Using the graph of the spectral brightness coefficient, one can estimate the size and productivity of crops, determine the amount of moisture in plants, identify plant communities prone to drought or waterlogging, and plants affected by diseases [25]. Synthesis options using the near-infrared spectrum for visual analysis of the state of agricultural land are the most representative. Infrared images are characterized by high contrast and allow you to reliably separate open ground from developing seedlings and analyze their condition. According to agronomists of the A.I. Barayev, wheat was sown from 05/12/2021 to 05/25/2021 and foci of weeds were poisoned from 06/17/2021. The graph of the spectral luminance coefficient of the obtained original image is shown in Figure 2, i.e., before the poisoning, the line of the spectral luminance coefficient of weeds is located higher.

Image segmentation is based on sequential enumeration, during which each image pixel is compared with a reference pixel and a measure of similarity is calculated. If the similarity measure does not exceed the specified value, then the class of the reference pixel is assigned to the current pixel. This research paper reviewed 25 Law's texture masks to obtain informative textural features used in image analysis. As a result, there was a noticeable difference in the images obtained from each texture mask, i.e., some images well distinguished homogeneous areas, and heterogeneity appeared in some results.

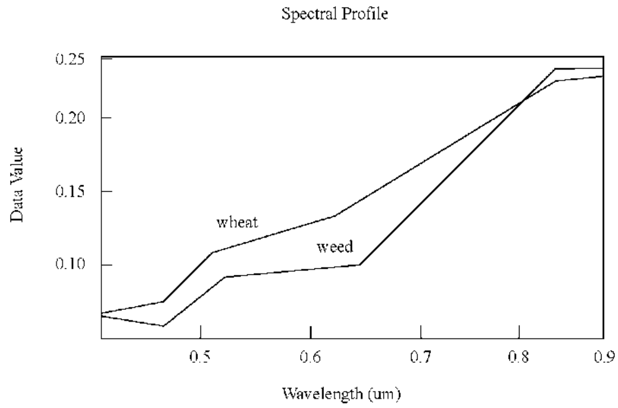


Figure 2. Spectral brightness coefficient of wheat and weeds

3.2. Apply informative masks to identify negative factors affecting wheat

Experiments were carried out with images of all 25 texture masks of size 5×5, which were possible in the MATLAB programming environment. More precisely, according to the cadastral number 01-012-025-040:42, calculations were made for various periods of the growing season of wheat sown on the land. Using the methods of orthogonal transformations and the vector of informative textural features, texture Law's masks were superimposed on the experimental area and the informative Law's mask was determined. The percentage value of the Law's mask did not significantly deviate from the result. The percentage of weed coverage for different growing seasons is shown in Figure 3.

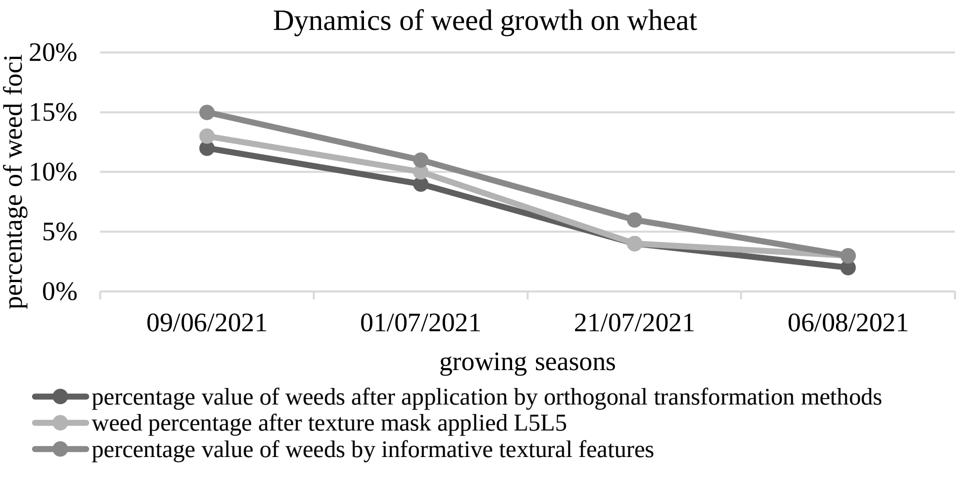


Figure 3. Dynamics of weed plants in different growing seasons

To perform spectral analysis, the image was divided into frequencies. On the images, it is possible to select areas for analysis that are conditionally considered stationary (in other words, quasi-stationary) and sufficient to obtain statistically final results. Figure 4 shows the result of clustering after applying the Haar orthogonal transformation [26], where the proportion of weed foci is 12%. Wheat germination is 35% and wheat tillering is 22%, unsown field is 5%.

When analyzing the texture of color images, additional characteristics of their properties are introduced, depending on the measurement of the intensity level of each color and their distribution in the image area. The current state of the text parsing problem is explained by the wide variety of text objects and the different nature of the tasks to be solved, as well as the large number of proposed methods. Figure 5 shows the clustering result obtained after applying the method of informative textural features, where 15% are weed foci, 5% are an unsown field, 33% are wheat seedlings, and 15% are tillering.

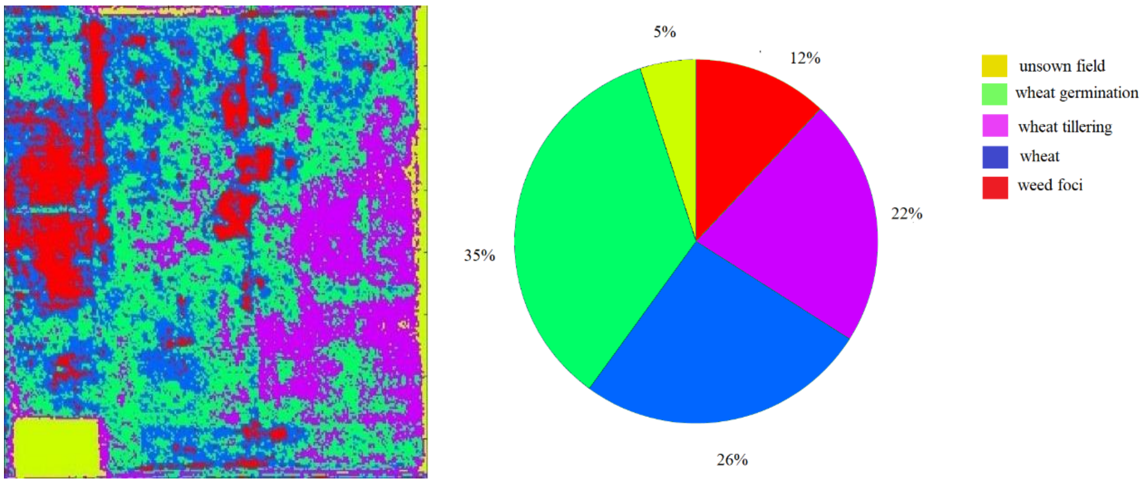


Figure 4. Clustering result of orthogonal transformation method (Haar)

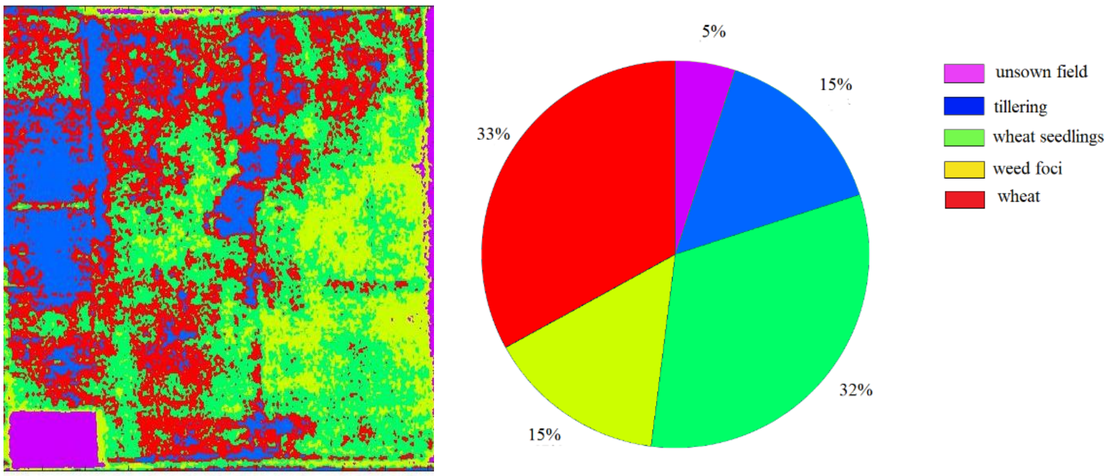


Figure 5. Result of clustering by the method of informative textural features

Texture energy measurements developed by K.I. Laws have been used for many different applications. These measurements are calculated by first applying small convolution kernels to the digital image and then performing a nonlinear windowing operation. In Figure 6, we see that according to the clustering results obtained after applying the L5L5 texture mask, weed foci in wheat become more pronounced and the share of the percentage is 13%, unsown field -5%, tillering -23%, wheat seedlings -26%.

One of the methods for studying textural features, the methods of orthogonal transformations, has shown its effectiveness in identifying factors that adversely affect the growth of crops. As a result of the applied method of textural features-methods of orthogonal transformations, a focus on weeds was revealed. As a result of Laws L5L5 texture mask methods, orthogonal transformations, and informative textural features, weed foci coincided as shown in Table 2.

As a result of experiments carried out during 4 growing seasons, one of the texture analysis methods was created using the Law’s texture mask. When analyzing aerospace images, we deal with various textures.

According to the results of the implementation of texture analysis methods, one can distinguish coniferous or deciduous forests, and fields sown with cereals or legumes. It is also possible to distinguish crops affected by pests and desert territories. The software system can be trained by examples using algorithms based on brain-computer or other approaches commonly used in machine learning. After training, the system will be able to predict the values of the parameters. In further research, Laws texture masks can be used as feature vectors associated with convolutional filters in machine learning, as it satisfies the weight conditions of neural networks.

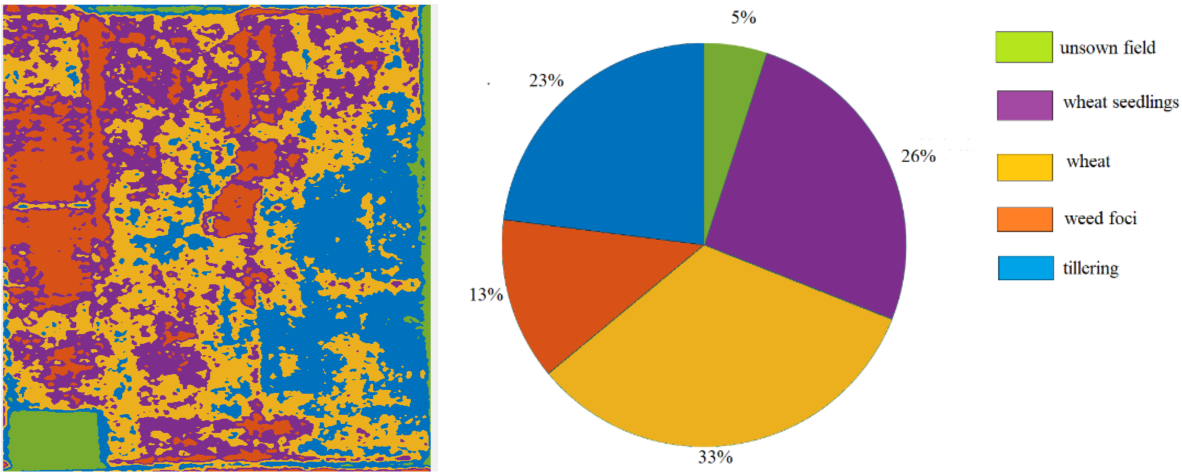


Figure 6. Clustering result of Law's L5L5 texture mask

Table 2. Results of the value of clustering by textural features

Data methods	9.06.2021	01.07.2021	21.07.2021	06.08.2021
Orthogonal transformations (average value)	12%	9%	4%	2%
Law's mask	13%	10%	4%	3%
Informative textural marks (T12, T8, T16)	15%	11%	6%	3%

4. CONCLUSION

In this paper, we considered a land plot under the cadastral number 01-012-025-040:42, owned by the A.I. Barayev Research Institute. In 2021, wheat was sown here. The growth dynamics of weeds, a factor negatively affecting the growth of wheat, were determined using Law's texture masks. From the obtained 100 images, the L5L5 texture mask was clearly distinguished from 25 possible texture masks for homogeneous areas. Clustering was carried out on images obtained by using the L5L5 texture mask. According to the coefficients of the spectral brightness of homogeneous areas in these images, pockets of weeds and wheat crops were distinguished. The result coincided with the result of applying the methods of orthogonal transformation in 9 works. Compared to the method of orthogonal transformations, the method of using Law's texture masks differs in the speed of calculation time. In further studies, the vectors of indicators can be associated with negative factors, namely, weed foci. The software system can be trained, for example, using brain-computer algorithms or other methods commonly used in machine learning. After training, the system will be able to predict variable values.

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REFERENCES

[1] Z. Omarkhanova, O. Misnik, G. Mataibayeva, G. Mukasheva, G. Zholdoyakova, and S. Ramazanova, "Influence of environmental factors of influence on the volume of financing in the agro-industrial complex," *Journal of Environmental Management and Tourism*, vol. 13, no. 3, Jun. 2022, doi: 10.14505/jemt.v13.3(59).18.

[2] N. Sharma and A. Verma, “Performance comparison of texture based approach for identification of regions in satellite image,” *International Journal of Computer Applications*, vol. 74, no. 2, pp. 10–15, Jul. 2013, doi: 10.5120/12856-9410.
[3] S. Nukeshev, V. Slavov, N. Kakabayev, and M. Amantayev, "Mathematical modelling in 3D of opener with scatterer of the grain-fertilizer seeder", *Mechanics*, vol. 6, pp. 840-844, 2018, doi: 10.5755/j01.mech.24.6.22476.
[4] J. L. Tang, D. Wang, Z. G. Zhang, L. J. He, J. Xin, and Y. Xu, “Weed identification based on K-means feature learning combined with convolutional neural network,” *Computers and Electronics in Agriculture*, vol. 135, pp. 63–70, Apr. 2017, doi: 10.1016/j.compag.2017.01.001.
[5] X. Jin, J. Che, and Y. Chen, “Weed identification using deep learning and image processing in vegetable plantation,” *IEEE Access*, vol. 9, pp. 10940–10950, 2021, doi: 10.1109/ACCESS.2021.3050296.
[6] G. G. Peteinatos, P. Reichel, J. Karouta, D. Andújar, and R. Gerhards, “Weed identification in Maize, sunflower, and potatoes with the aid of convolutional neural networks,” *Remote Sensing*, vol. 12, no. 24, pp. 1–22, Dec. 2020, doi: 10.3390/rs12244185.
[7] S. Sabzi, Y. Abbaspour-Gilandeh, and G. García-Mateos, “A fast and accurate expert system for weed identification in potato crops using metaheuristic algorithms,” *Computers in Industry*, vol. 98, pp. 80–89, Jun. 2018, doi: 10.1016/j.compind.2018.03.001.
[8] O. Ağın and A. Taner, “Determination of weed intensity in wheat production using image processing techniques,” *Anadolu Journal of Agricultural Sciences*, vol. 30, no. 2, Jul. 2015, doi: 10.7161/anajas.2015.30.2.110-117.
[9] G. B. Abdikerimova, F. A. Murzin, A. L. Bychkov, X. Wei, E. I. Ryabchikova, and T. Ayazbayev, “The analysis of textural images on the basis of orthogonal transformations,” *Journal of Theoretical and Applied Information Technology*, vol. 97, no. 1, pp. 15–22, 2019.
[10] 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.
[11] 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.
[12] N. Ahmed, T. Natarajan, and K. R. Rao, “Discrete cosine transform,” *IEEE Transactions on Computers*, vol. 23, no. 1, pp. 90–93, Jan. 1974, doi: 10.1109/T-C.1974.223784.
[13] E. Feig and S. Winograd, “Fast algorithms for the discrete cosine transform,” *IEEE Transactions on Signal Processing*, vol. 40, no. 9, pp. 2174–2193, 1992, doi: 10.1109/78.157218.
[14] N. Balonin and M. Sergeev, “Quasi-orthogonal local maximum determinant matrices,” *Applied Mathematical Sciences*, vol. 9, no. 5–8, pp. 285–293, 2015, doi: 10.12988/ams.2015.4111000.
[15] K. J. Horadam, *Hadamard matrices and their applications*. Princeton: Princeton University Press, 2012.
[16] J. J. Benedetto and M. W. Frazier, *Wavelets: mathematics and applications*. Boca Raton: CRC Press, 2021.
[17] L. da F. Costa and R. M. Cesar Jr., *Shape analysis and classification: theory and practice*. CRC Press, 2010.
[18] M. Cancellaro, F. Battisti, M. Carli, G. Boato, F. G. B. De Natale, and A. Neri, “A commutative digital image watermarking and encryption method in the tree structured Haar transform domain,” *Signal Processing: Image Communication*, vol. 26, no. 1, pp. 1–12, Jan. 2011, doi: 10.1016/j.image.2010.11.001.
[19] D. Jiang, L. Liu, L. Zhu, X. Wang, X. Rong, and H. Chai, “Adaptive embedding: A novel meaningful image encryption scheme based on parallel compressive sensing and slant transform,” *Signal Processing*, vol. 188, Nov. 2021, doi: 10.1016/j.sigpro.2021.108220.
[20] J. Zuo, D. Cui, and Q. Li, “A novel slant transform-based image feature extract algorithm,” *International Journal of Embedded Systems*, vol. 9, no. 3, 2017, doi: 10.1504/IJES.2017.084688.
[21] S. A. Broughton and K. Bryan, *Discrete fourier analysis and wavelets: applications to signal and image processing*. Hoboken, NJ, USA: John Wiley & Sons, Inc., 2018.
[22] A. V. Zamyatin and A. Z. Sarinova, “Processing the algorithms, compression of hyperspectral images based on aerospace crossband correlation with and without losses,” 2016.
[23] A. Yerzhanova, A. Kassymova, G. Abdikerimova, M. Abdimomynova, Z. Tashenova, and E. Nurlybaeva, “Analysis of the spectral properties of wheat growth in different vegetation periods,” *Eastern-European Journal of Enterprise Technologies*, vol. 6, pp. 96–102, Dec. 2021, doi: 10.15587/1729-4061.2021.249278.
[24] J. R. Irons, J. L. Dwyer, and J. A. Barsi, “The next landsat satellite: the landsat data continuity mission,” *Remote Sensing of Environment*, vol. 122, pp. 11–21, Jul. 2012, doi: 10.1016/j.rse.2011.08.026.
[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, pp. 39–47, Jun. 2022, doi: 10.15587/1729-4061.2022.257431.
[26] M. Schirrmann, A. Giebel, F. Gleiniger, M. Pflanz, J. Lentschke, and K.-H. Dammer, “Monitoring agronomic parameters of winter wheat crops with low-cost UAV imagery,” *Remote Sensing*, vol. 8, no. 9, Aug. 2016, doi: 10.3390/rs8090706.

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