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Features of growth of agricultural crops and factors negatively affecting their growth

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ABSTRACT

This article is about methods of analyzing aerial images. Images from Planet.com for crops in North Kazakhstan owned by the Center for Cereal Production and Research. A.I. Barayev. The main goal of the research work is to develop and implement algorithms that allow identifying and distinguishing factors in aerial photographs that adversely affect the growth of plants during the growing season. Spectral brightness coefficient (SBC), normalized difference vegetation index (NDVI), textural features, clustering, and integral transformations are used to solve the problem. Particular attention has been paid to the development of software tools for selecting features that describe textural differences to divide texture regions into subregions. That is weeds, and pests in aerial images. The application of a set of textural features and orthogonal transformations to the analysis of experimental data is explored to identify regions of potentially correlated features in the future. The analysis of the received data made it possible to determine the characteristics of changes in the reflective capacity of agricultural plants and weeds in certain stages of the growing season. The obtained information is of great importance for confirming the observations from space remote from the aerial images.

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1. INTRODUCTION

The basis for this study is the features of the growth of crops during the growing season and the factors that negatively affect their growth in the research and production center of grain farming named after A.I. Barayev. The purpose of the study is to create a scientific and technical base for processing index images [1]–[6]. A further objective of the study is to identify factors that adversely affect crop growth, such as weeds, pests, and diseases. Now the study of this issue is relevant among scientists of different specialties-agronomists, chemists, biologists, and technologists.

This article focuses on the development of software tools for aerial image analysis, specifically texture analysis programs from normalized difference vegetation index (NDVI). To analyze the results of remote sensing of the Earth and its underlying surface, as a rule, three intervals of the electromagnetic radiation spectrum are distinguished and taken into account: visible, infrared, and microwave. This article considers the brightness values at different intervals of the electromagnetic spectrum to obtain useful intervals for the selection of objects for study, for example, the selection of plant species and damage to crops, i.e. let's say weeds.

For comparison, statistical methods are used for a large sample of data from two images, which require large computational resources, as well as NDVI indices, and the use of NDVI indices has one drawback: for one NDVI value, there correspond many pairs of spectral brightness coefficient (SBC) values, which entails ambiguity in the results of the study. To circumvent this problem, the following procedure is used: based on the values of the SBC, an NDVI is created an index image, which also requires additional calculations. This article deals with spectral transformations based on orthogonal matrices [7]–[12]. A total of 6 types of transformations are considered. It is believed that the properties of texture features, such as the order/disorder ratio, the percentage of areas with "anomalous" texture, obtained for different images, as well as different spectral coefficients, can be additionally related to the values of characteristics of weeds, plants, and crops. Software products that enable accurate texture analysis can be successfully used in various fields of science and industry. These are primarily research institutes in the field of agriculture and agro-industry.

When processing aerial images, the researchers also pay attention to different textures. If it is a coniferous or deciduous forest, if the field is sown with grain or nuts, it is possible only with structural features. You can also determine if the forest is infested with pests or if the area is abandoned. Another area of research where this method can be used effectively is the diagnosis of human internal pathology, including malignancy, using images taken with a thermal camera. The fundamental difference between our research ideas and existing counterparts lies in the proper application of mathematical methods and their deeper investigation. For example, we know of over two hundred textural features, but scientific assessments typically use about fifty of them. At the same time, in practice, most often only 3-4 features are used, for example, when processing satellite images. This means that the original image is fully revised. The same applies to the application of integral transformations. For example, when studying the strength of metals under stress, the Haar transform is used to characterize cracks. And also, in research in the field of plants, the effectiveness of spectral changes was revealed.

The results obtained can be applied in automated image analysis systems, used in scientific research and industry. Its use in industry reduces the cost of fertilizers from the destruction of weeds and, in some cases, improves the quality of agriculture. Xiao *et al.* [13] presents the theoretical and practical results of using orthogonal transformations based on Walsh functions for information compression when transmitting aerospace images over a communication channel. Abdikerimova *et al*. [14], a spectral transformation was used on various orthonormal bases of images obtained with a transparent electron microscope. The efficiency and reactivity of technological processes, porosity, and diffusion coefficient have shown the effectiveness of determining the degree of disorder of plant cell walls from microphotographs to determine the properties of plant materials. A feature of this work is the application of orthogonal transformations to aerospace images. In particular, the effectiveness of these methods in determining the factors that adversely affect the growth of crops, i.e. weeds.

2. METHOD

Much work has been done recently on texture analysis of dynamic textures and color images. When analyzing the texture of color images, additional symbols of their properties are introduced, based on measuring the intensity levels of each color and its distribution in the image field. In the analysis of dynamic structures that change over time, space-time is introduced as a third dimension in addition to the two space coordinates. In this case, all texture changes are modeled by moving the individual parts that do not change (movement, rotation). The current state of the texture analysis problem is explained by a large number of proposed methods, as well as a wide range of textured objects and the variety of tasks to be solved.

The texture is one of the most important features used to describe desired areas or properties on the surface of an image based on grayscale dependence on space [15]. Despite the presence of textures in images, there is no single formal approach to describing textures and their rigorous definition. Methods of plot analysis are usually developed individually for each case as shown in Figure 1.

However, despite the absence of a formal approach and a strict definition of the story, four approaches can be envisaged in the definition-construction phase [16]: i) statistical approach: the texture is calculated as a quantitative characteristic of the distribution of intensity values in the image area; ii) structural approach: the texture is considered as a set of textured primitive textures arranged in a simple or repetitive order; iii) fractal approach: the description of a wide range of processes and phenomena, such as limited diffusion aggregation processes, the formation of sticky fingers in porous media, diffusion processes called leaks and characteristics of clouds, terrestrial and other natural objects, a new direction called fractal geometry found out. In such methods, the authors consider the object not as a texture, but as a fractal [17]. Many authors state that natural surfaces are isotropic fractals in space and that the two-dimensional intensity field of such surfaces is fractals; and iv) spectral approach: Fourier and wavelet analysis are used to work with the texture of the image at different scales. Spectral analysis is a very effective tool for analyzing signals and images. This is because the spectrum is very sensitive to various changes in the structure of signals and images. To perform spectral analysis, one must first divide the signal or image into frequencies. It uses a different set of basic functions. Corresponding algorithmic transformations are: cosine, Hadamard, Haar, and italic. called algorithm transformations. The Haar and Dobeshi transformations, on the other hand, are simpler types of wavelet transformations. These methods, which are consistent with the theory of signal processing, can be applied to stationary random processes. However, areas can be selected from the images that are conventionally considered stationary (quasi-stationary) and sufficient for analysis to obtain statistically finite results.

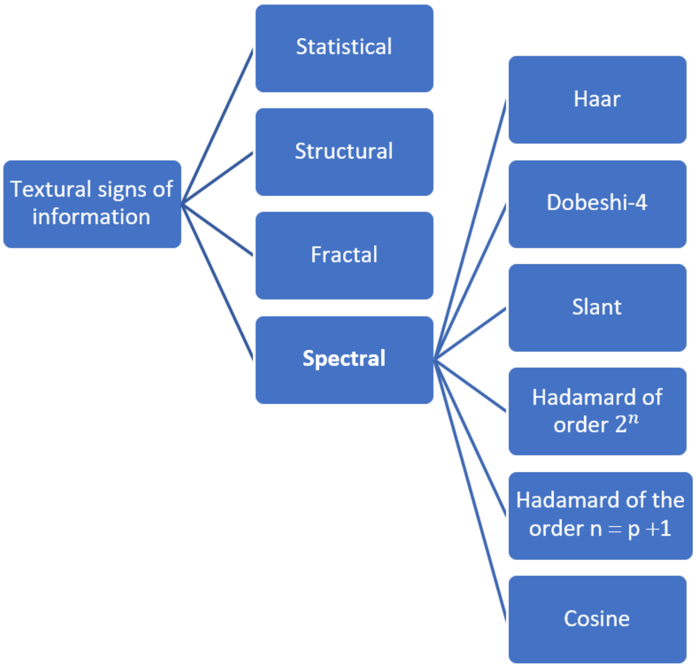

Figure 1. Texture imaging methods

Spectral transformations in a-dimensional case can be written down in a such way as $H\vec{u} = \vec{a}$ where H–is the transformation matrix, whose rows form an orthonormal basis in the corresponding linear space; $\vec{u}$–vector representing the sampling of the original signal; $\vec{a}$–vector of spectral coefficients, characterizing how much one or another basis function (harmonic) is represented in the vector $\vec{u}$ (that mean in the original signal). In the two-dimensional case for images, the spectral transformation is written in the form $HUH^T = A$ where H^T is a transposed matrix, U is a square fragment of the original image, A a matrix containing spectral coefficients. That is, we believe that the conversion is applied to the image fragment. Huang *et al*. [18] explained methods of orthogonal transformation are shown for distinguishing agricultural cereals and their weeds. 6 methods of orthogonal transformation are presented in this work:
– Cosine [19].
– Hadamard order 2^n [20].
– Hadamard order $n = p + 1, p = 3\ (mod\ 4)$– a prime number, i.e. based on the legendre symbol [21].
– Haar [22].
– Slant [23].
– Dobeshi-4 [24], [25].

3. RESULTS AND DISCUSSION

The experiment was carried out in the MATLAB environment using the image processing toolbox. The initial data was taken from the open-access Planet.com. The factors that negatively affect the growth of wheat, in particular the negative impact of weeds on the vegetation, belong to the research and production grain center named after A.I. Barayev in the North Kazakhstan region (Figure 2).

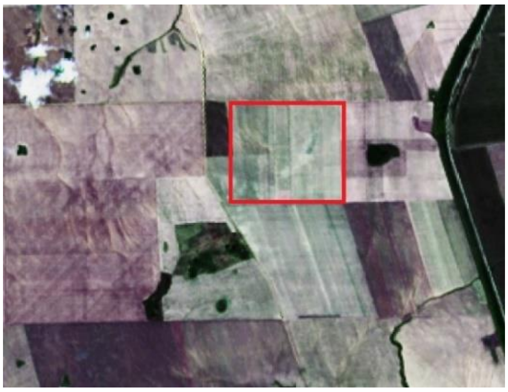

Figure 2. The original image

In order to perform spectral analysis, the signal or image must first be broken down into frequencies. To do this, several sets of basic functions are used. The corresponding algorithms are called transforms cosine, Hadamard, Haar, and diagonal. Note that the Haar and Daubechies transform are the simplest wavelet transforms. The program is implemented in a MATLAB environment and allows spectral transformations of six types: i) cosine, ii) Hadamard order 2^n, iii) Hadamard order $n = p + 1, p = 3\ (mod\ 4)$-a simple number, i.e. based on the Legendre symbol, iv) slant, v) Dobeshi-4, and vi) Haar.

The calculation is performed in the MATLAB environment and is used for image analysis. The image is divided into separate parts using the software. In the study of texture images, various non-standard methods can be used using orthogonal transformation. For example, the original image is divided into non-intersecting square windows. Experiments show that it is better to reduce the size of the window: 8×8, 16×16, and 32×32. We perform an integral transformation on each window. We also set some spectral coefficients to zero, such as high-frequency coefficients or some parts of the spectrum. In the two-dimensional case, the frequency spectra have the form of a matrix. Let's place the elements of the matrix in the form of vectors. For example, consider the rows of a matrix located one after another at the end. In vector data, we subtract the coefficients of the spectra that have been zeroed out from the resulting vector. As a result, we perform the procedure of clustering these vectors. The results of image processing by the methods described above are presented in Figure 3.

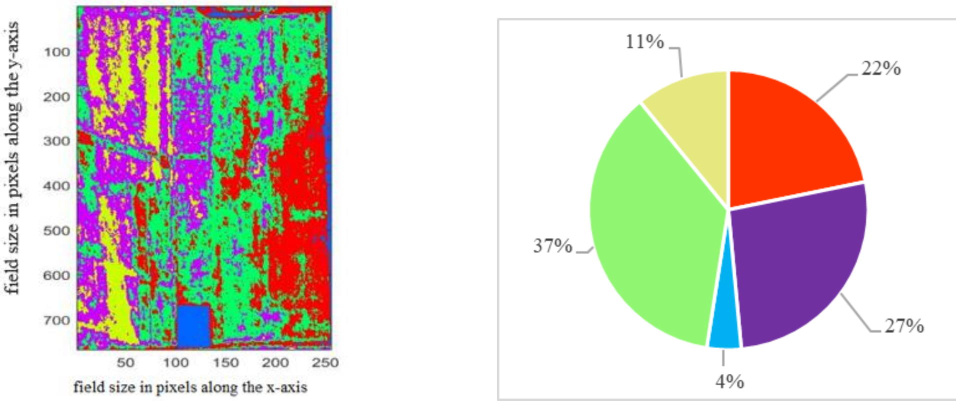

Figure 3. Haar transformation is used, the result of clustering on the lower frequency of the spectrum

According to experts from the A.I. Barayev Center for Cereal Production and Research., wheat was sown from 05/12/2021 to 05/25/2021. Weed foci have been hybridized since 06/17/2021. The Table 1 shows the percentage of weeds. 06/17/2021 weeds were hybridized and harvested from 08/18/2021. The Table 1 shows the percentage of weeds for different growing seasons. One of the methods of orthogonal transformations-the Haar method-was used to determine the foci of weeds for different periods of vegetation, i.e. number: i) 06/10/2021, ii) 07/10/2021, iii) 07/21/2021, iv) 08/6/2021, and vi) 09/14/2021. The graph of the result of the study is shown in Figure 4.

Table 1. Identification of weeds by orthogonal transformations in different growing seasons

Data and methods	10/06/2021 (%)	01/07/2021 (%)	21/07/2021 (%)	06/08/2021 (%)	14/09/2021 (%)
Haar	37	9	6	9	3
Dobeshi-4	37	8	5	6	3
Cosine	37	10	5	8	3
Hadamard of the order n = p +1, p ≡ 3(mod4) – prime number, i.e. based on Legendre's symbol	37	9	6	9	3
Hadamard of order 2^n	37	9	5	9	2
Slant	37	9	6	8	3

Image analysis based on SBC allows you to recognize the type of plant and changes in plants by growing seasons. Our research allows us to detect whether a plant is healthy, if not, what negative factors have affected the plant: disease, wilting, lack of fertilizers, insect damage, and so on, as well as predict yield. Figure 5 shows how it is possible to organize the partitioning of the spectrum of brightness coefficients, for further recognition of the type of crop and its normal growth. During the growing season 10/06/2021 in the Table 2, the percentage of weeds visible by all methods is very high. After the hybridization of weeds during different growing seasons, the following graph shows as shown Figure 5 the dynamics of their reduction and increase in productivity as shown Table 2.

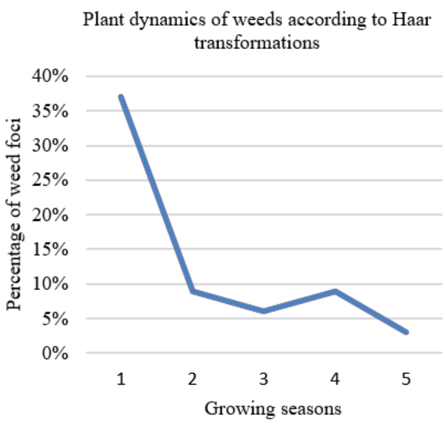

Figure 4. Weed plant dynamics

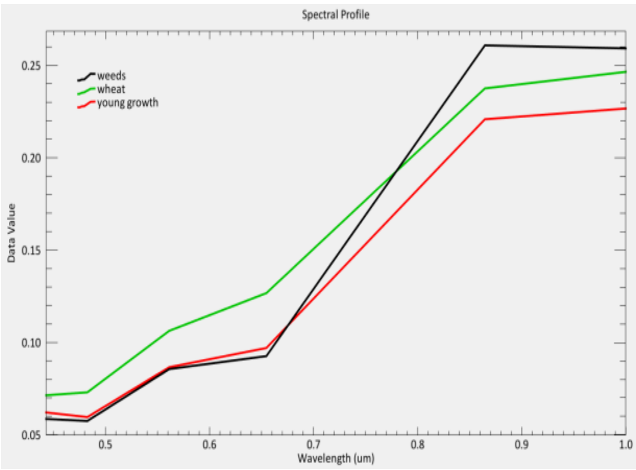

Figure 5. Spectral coefficients of the brightness of wheat, weeds, wheat shoots during the growing season 10/06/2021

Table 2. Detection of weeds and millet on orthogonal transformations before the application of herbicides

Method	10/06/2021		
	Weeds (%)	Young growth (%)	Wheat (%)
Haar	37	26	37
Dobeshi-4	37	28	35
Slant	37	27	36
Hadamard order 2^n	37	27	36
Hadamard order $n = p + 1, p = 3\ (mod\ 4)$ - a prime number, i.e., based on the Legendre symbol	37	27	36
Cosine	37	27	36

After processing the multispectral grayscale image (NDVI), the methods of orthogonal transformation and the efficiency of their use are determined. In the course of the research work, reference values of the land plot were created using spectral brightness coefficients. Based on the reference values created in each growing season, we see the effectiveness of the methods used. After applying the methods of orthogonal transformation, homogeneous areas were identified on aerospace images, compared with the actual data provided by the agronomists of the A.I. Barayev Institute, and the percentage of weeds was calculated. The disadvantage of these methods is the inability to identify crop pests and diseases in aerospace images. The mathematical description of these research methods requires the accuracy and processing time of a single image used.

4. CONCLUSION

The work is dedicated to the investigation of multispectral images and their segmentation through integral transformations. In this study, wheat fields of the Akmola region of Northern Kazakhstan were considered. Data provided by A. I. Barayev Grain Research and Production Center: analysis of wheat crops, weed pickling, and wheat harvesting time. The original images from the work were taken from Planet.com, where daily information about the site is available. Because the aerospace NDVI images of crop images were grayscale, they were segmented after the spectral transformation result. Methods of orthogonal transformations in different periods of vegetation have shown their effectiveness in identifying weeds.

As a result, the following questions on orthogonal transformation were identified: i) as a result of the study using cluster images, a zone of local weed poisoning was identified; ii) as a result of local etching, the earth's natural fertility is preserved; and iii) the specialists were recommended to effectively calculate the cost of pickling the area of weed growth in the field based on the percentages received.

The disadvantage of this method is that, as a result of calculating methods in a large window, when calculating the boundaries of separation of different areas from each other, they turn out to be rough, that is, the error is large. One of the methods of studying structural characteristics, orthogonal transformations, has proven effective in determining factors that negatively affect plant growth. Due to the large data of aerospace images, it takes a long time to achieve the result. Therefore, in the future, the software can be trained in other ways that are often used in machine learning to automate a system. After training, the system can predict the parameter values.

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