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Remote monitoring of agricultural land using multispectral satellite imagery Sentinel 2 by contour analysis

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Abstract. This article describes the method of remote monitoring of agricultural land using Sentinel 2 satellite imagery. The NDVI index identifies problem areas of an agricultural field. The local filtering algorithm smoothes images for further processing. An algorithm for filtering images by threshold obtained experimentally is also described. An algorithm for detecting contours by the Rosenfeld method of healthy vegetation is described.

1. Introduction

Today, one of the most advanced, effective and reliable sources of information on the properties of agricultural land and on the state of crops is data from satellite imagery of the Earth.

Satellite monitoring allows you to receive uniform and comparable in quality information at a time for large areas, which is almost unattainable with any terrestrial and near-Earth surveys.

Agricultural land is a strategic resource of the state, determining the food security of the population. The success of agribusiness depends primarily on the ability of managers at various levels to competently manage land resources and other productive assets. Effective management of resources and assets is largely determined by the awareness of the location, shape, size and configuration of the cultivated fields, fertility, agrochemical and agrotechnological properties of soils, and localization of infrastructure facilities. And, of course, effective planning and management in the agrarian sector is unthinkable without information on the yield of agricultural crops.

Agricultural production is not static. Every year crop rotations change, new crops are planted. In varying degrees, a farmer faces the need to monitor the annual cycle of his agricultural production. One of the most advanced, effective and reliable sources of information on the properties of agricultural land and on the state of crops is Earth remote sensing data.

Monitoring is an integral part of management, which consists in continuous observation and analysis of the activities of objects with tracking the dynamics of changes. Space monitoring of agricultural crops consists in continuous multiple obtaining of information on the qualitative and quantitative characteristics of agricultural objects and processes with precise geo-referencing by processing data obtained from remote sensing satellites. Space monitoring allows to obtain homogeneous and comparable in quality information at a time for large areas, which is practically unattainable with any terrestrial and near-Earth surveys.

To date, many methods are used to identify signs that allow analyzing the conditions of crops, identifying boundaries, and determining their belonging to a particular type of planting. The most



commonly used feature in such studies is the vegetative index of the normalized difference NDVI (Normalized Difference Vegetation Index) [1].

The NDVI is a quantitative indicator of photo synthetically active biomass [1], calculated by the formula

$$NDVI = \frac{\rho_{NIR} - \rho_{RED}}{\rho_{NIR} + \rho_{RED}}$$

where ρ_{NIR} is the reflection in the near infrared region of the spectrum,

ρ_{RED} – reflection in the red region of the spectrum.

To display the NDVI index, a standardized continuous gradient scale is used, showing values in the range from $-1..1$ in% or in the so-called scaled scale in the range from 0 to 255 (used for display in some Earth remote sensing packages, corresponds to the number of grayscale). Due to the features of the reflection in the NIR -RED regions of the spectrum, natural objects not related to vegetation have a fixed NDVI value, (which allows using this parameter to identify them):

Table 1.

Object type	NDVI value
Dense vegetation	0.7
Sparse vegetation	0.5
Open soil	0.025
Clouds	0
Snow and ice	-0.05
Water	-0.25
Artificial materials (concrete, asphalt)	-0.5

2. Statement of the problem

The source used multispectral satellite images Sentinel_2b (as of 2018.03.21). Multispectral satellite images of Sentinel_2 have a resolution of 10 meters, that is, one pixel of the image corresponds to a section of the earth's surface with a size of meters. Test fields are located on the territory of Pakhtakor district of the Jizakh region of the Republic of Uzbekistan [2].

3. Method of solution

Algorithm of monitoring on the example of one field.

Step 1. The vegetation index was calculated from the near and infrared images using the formula (1). Next, loading the vector layer of the field, cut the field from the bitmap image. Figure 1 shows the result. What the image displays is a gray tint box with an extension of m.

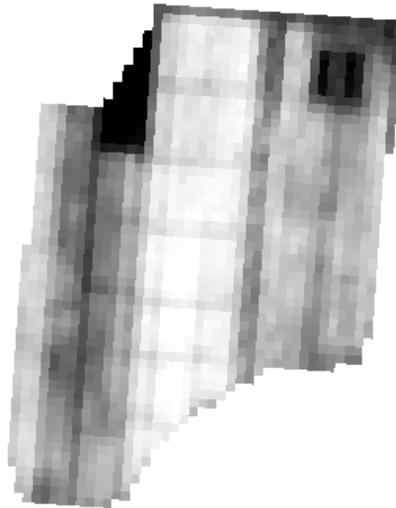


Figure 1. image calculated by the formula NDVI.

Step 2. To improve the image quality, perform the image smoothing procedure using local filtering. The essence of the method lies in the fact that during processing, a rectangular window slides along the raster, which picks up the pixels used to calculate the color of some current pixel. If the neighborhood is symmetric, then the current pixel is in the center of the window. The basic operation of such a filter can be represented as the following dependency:

$$F(x, y) = \frac{1}{K} \sum_{i=i_{\min}}^{i_{\max}} \sum_{j=j_{\min}}^{j_{\max}} P_{x+j, y+i} \cdot M_{i-i_{\min}, j-j_{\max}}$$

where P is the color value of the current pixel; F - new pixel color value; K - normalization coefficient; M - two-dimensional array of coefficients that defines the properties of the filter (such an array is called a mask). In practice, a filter was used with 3×3 a window that is obtained with $i_{\min}, j_{\min} = -1$, and $i_{\max}, j_{\max} = +1$. The result of the smoothing function is shown in Figure 2.

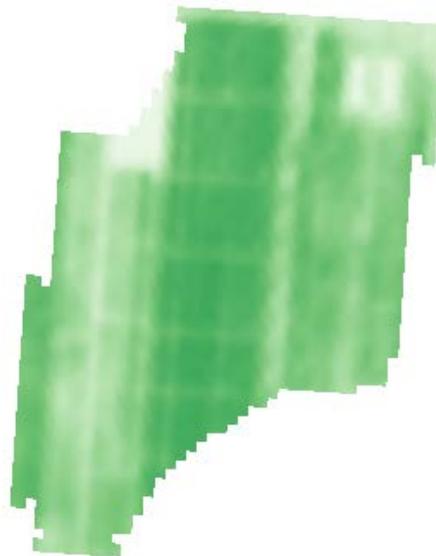


Figure 2. Image with pixel extension 2×2

At the third step, for the convenience of finding problem areas, we invert the images and get the result. In the image (Figure 3), the areas highlighted by a pencil are darker, which means a low vegetation index in these pixels.

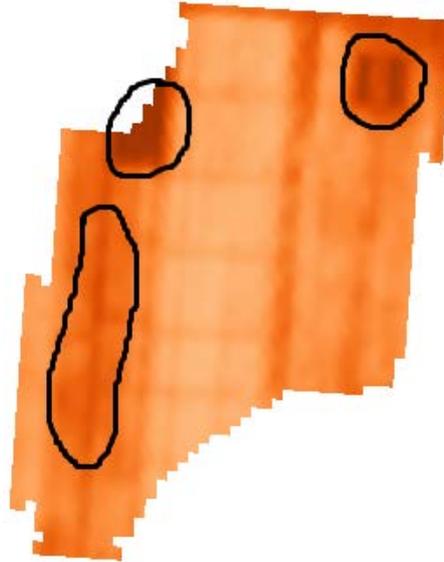


Figure 3. Inverted image.

Step 4. In order to distribute the field into two classes, namely the healthy areas of the field with high NDVI and the non-healthy areas of the field with low NDVI, it is necessary to perform a binarization procedure. To binarize an image, we use the histogram of the brightness distribution with the threshold obtained experimentally.

To separate an object from the background in the presence of noise, it is necessary to perform a raster binarization procedure, which will result in the separation of the raster pixels into two classes: the object and the background: object and background. Let be $R = \{r_{m,n}\}$ $m = \overline{1, M}$, $n = \overline{1, N}$ – an image containing a separate dynamic object, then the binarization rule for this image will be:

$$\hat{r}_{m,n} = \begin{cases} 0 & \text{if } r_{m,n} \leq \beta \\ 255 & \text{if } r_{m,n} > \beta \end{cases}$$

where $\hat{R} = \{\hat{r}_{m,n}\}$ – binarized image, β – threshold value, which is selected by the histogram of pixel brightness distribution $H = \{h_k\}$, $k = \overline{0, 255}$ current raster.

$$\beta = k, \text{ if } \frac{H_k}{\sum_{l=0}^{k-1} H_l} \leq 0,15$$

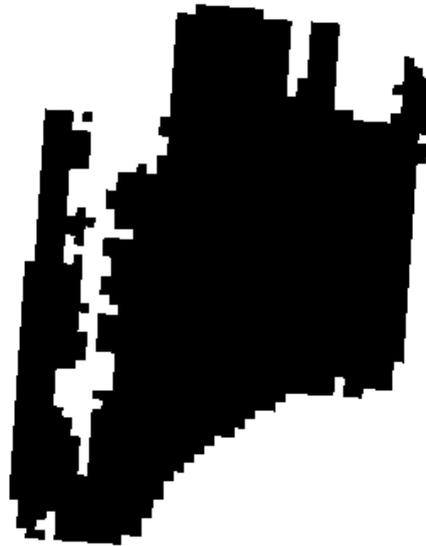


Figure 4. Binary image.

Step 5. After performing the binarization procedure with a certain error, we have two classes, which allows us to identify areas of the field with healthy vegetation from these two classes.

Since most of the information about the shape and orientation of the object is concentrated in its boundary points, which form the contour of the object [3], there is no need to store all points of the object. The contour of an object is a collection of points (pixels) separating the object from the background. Computer vision systems use several contour coding methods, the most well-known of which is the complex-valued code, in which the contour is encoded by a sequence of complex numbers defining the offset of the current contour point relative to the previous one. Each displacement vector is represented by $a + i \cdot b$ a complex number of a species, where a is the point displacement along the axis X , and b is the displacement along the axis Y , i is the imaginary unit. To uniquely determine the position of the contour in the raster, it is also necessary to store the starting point of the contour, which determines the position of the contour relative to the axes of the raster coordinates. The contours are always closed and cannot have self-intersections.

This allows you to uniquely determine the path of the circuit bypass (up to the direction of the circuit - clockwise or counterclockwise). The last contour vector always leads to the starting point.

To form a contour, Rosenfeld's algorithm [4] is used, which consists of several steps. In the first step, you need to scan the scene in order to find the upper left border pixel of the contour. In the second step, you must trace the contour line, according to the boundary points. In the third step, you need to form a code that will describe the contour. Thus, the output of the Rosenfeld algorithm will form the contour of the selected object, which is a vector of complex numbers, $\Gamma = \{\gamma_k\}_{0, K-1}$ formed according to the following rule:

$-1+i$	i	$1+i$
-1		1
$-1-i$	$-i$	$1-i$

Figure 5. Coordinates of an elementary vector with complex-valued coding.

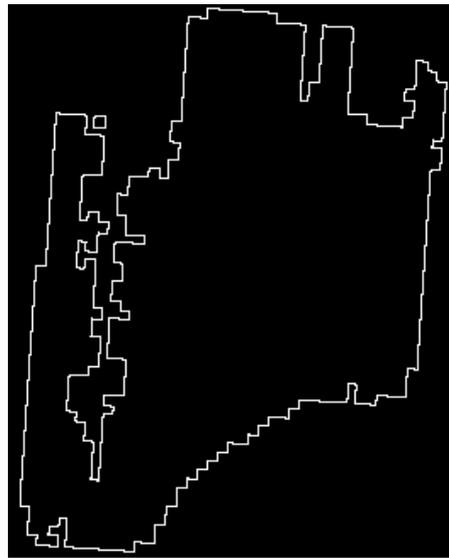


Figure 6. Contour of healthy vegetation.

4. Discussion of results and conclusions

Using the interpretation of information on changes in the spectral brightness of vegetation during the vegetation period and the NDVI (Normalized Difference Vegetation Index), one can judge their agrotechnical, ameliorative status, etc. by the tone of the field image.

The monitoring results provide more objective and accurate information when combined with current and fairly accurate farmland maps. The monitoring tasks themselves are solved on this background more efficiently and at significantly lower costs.

Thus, the conducted studies clearly demonstrate that satellite imagery materials are a reliable source of objective, unbiased information about the structure of crops of agricultural crops. The developed approach and the recognition features of agroecosystems found on its basis can be applied to carry out detailed interpretation of agricultural land, explaining the course of vegetation curves of agroecosystems. The presence of a series of such maps for different years will allow for a qualitative analysis, effective planning and control of land use.

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