Automatic recognition of the number of channels in unidentified multispectral data

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***Abstract*—The work is devoted to the development of a method for identifying unknown parameters of multizone Earth images got from remote sensing systems. The method allows automatically to determine the method of alternating spectral channels and calculate their number for images stored in files of uncompressed formats. A theoretical justification based on a change in the shape of the Fourier spectrum with a change in the method of alternating channels in the data file is presented, features of the shape of the spectrum are revealed that allow reliable identification of the required characteristics. The results of applying the algorithm to real Earth images from space are presented, its applicability limits are indicated, and recommendations are given for choosing specific parameters of the algorithm.**

Keywords—remote sensing data, image recognition, Fourier analysis, multispectral data

I. INTRUDUCTION

Nowadays, no modern sphere of human activity can do without the use of digital images, starting from medicine and biology and ending with images of the Earth from space. Of particular interest are multiband images [1], when each band of a multidimensional image has a certain piece of information about an object of interest. Such images have gained particular popularity in the field of remote sensing since the use of a combination of different channels allows us to obtain a wide range of various derivative characteristics [2,8].

There are three ways of the uncompressed multiband image storing: BSQ, BIL, and BIP [3]. The BSQ format stores information into an image file one channel at a time, wherein, information about each of the channels is conditionally presented independently of other ones. The BIL-format supports line by line recording of all channels, data is stored into the file sequentially row by row. Using the BIP-format all information is stored into the final file pixel by pixel, that is, firstly, information is stored in the first pixel of the first image channel, secondly, the first pixel of the second image channel and so on. The right choice among BIL, BIP, and BSQ-formats for multiband data is key to the success of the correct image opening on an equal basis with the knowledge of image size (the number of lines and colons).

Unfortunately, in some cases, for example, when the header file is lost, or if image storage is damaged, it is impossible to read the image with specialized software products due to the loss of information about both the image size and the multiband image storing formats [4]. Accordingly, it poses the challenge of developing a methodology for the automated determination of the indicated characteristics that would make it possible to subsequently read the data of image correctly. The proposed methodology is based on the Fourier analysis [5] of the image presented in the row vector of sequence of bytes of the source file. Fourier analysis allows us to identify patterns alternation of image content, presented in a one-dimensional discrete form, since the Fourier spectrum has sensitivity to the periodic components of the signal, expressed in the appearance of peak values of the amplitude component at frequencies corresponding to the relative frequencies of such components. An analysis of the location of the peaks of the Fourier transform can reveal the presence and parameters of periodic components in the row vector of the identified file, and then find the multiband image storing formats and the number of image channels.

II. THE THEORETICAL BASIS OF THE DEVELOPED METHOD

At the first step in the development of the algorithm, it is necessary to establish general patterns that arise with a particular multiband image storing. To identify these patterns, four-band test images 100×100 pixels in size were generated, where each of the bands takes a fixed brightness value, which is a random number in the range from 0 to 255. The resulting image is laid out in a row vector in three different ways, corresponding to three different multiband image storing data*:* BSQ, BIL and BIP. Typical brightness profiles of the obtained one-dimensional signals are presented in the Fig. 1—3, a. At the next stage, a Fourier transform is applied to each of the generated one-dimensional discrete signals. The results are presented in the Fig. 1—3, b.

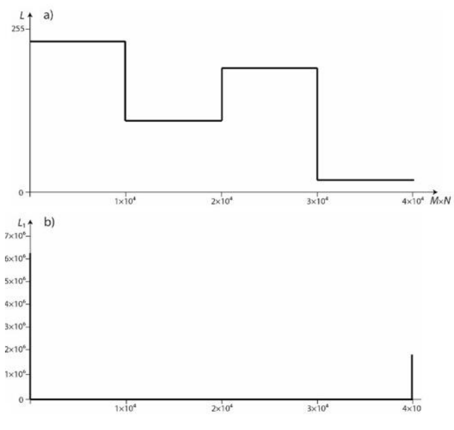

Fig. 1. The one-dimensional discrete image signal in BSQ format: a) brightness profile; b) Fourier transform.

As can be seen from Fig. 1, a brightness profile has a quasiperiod equal to the number of pixels in the image region. The Fourier image of such an image consists of the two most conspicuous peaks, the first of which is at the origin, and its value is equal to the total brightness of the pixels in the image, the second peak is at the end of the coordinates and its value is equal to the amplitude of the first harmonic.

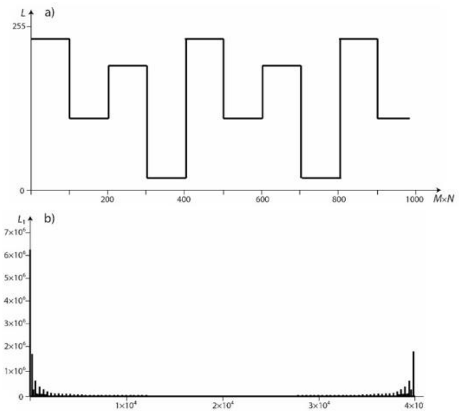

Fig. 2. The one-dimensional discrete image signal in BIL format: a) brightness profile (the first 1000 samples are shown); b) Fourier transform.

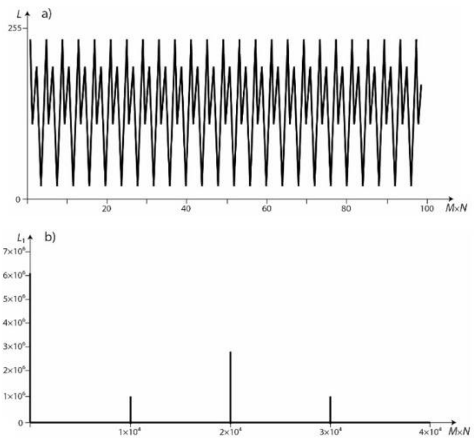

Fig. 3. The one-dimensional discrete image signal in BIP format: a) brightness profile (the first 100 samples are shown); b) Fourier transform.

The values of the remaining components are significantly lower than the peak ones and are grouped around the central one. From Fig. 2 it follows that the vector line in the BIL format has a periodicity equal to the product of the number of lines by the number of channels, the quasi period will be equal to the width of one line. The Fourier transform is similar to the first situation, however, minor peaks appear on it with an interval equal to the width of the image row, with each *k*-th peak degenerating to zero, where *k* is the number of channels. The most interesting case is shown in the Fig. 3. In addition to the first peak with a height equal to the total brightness of the image, there are (*k*-1) peaks located at frequencies equal to $P = iMN, i = \overline{1,k}$. Therefore, if the format for storing multiband data corresponds to BIP, then by analyzing the Fourier image, one can find the number of channels of a multi-dimensional image. Thus, it is necessary to develop an algorithm that would detect peaks of the Fourier transform against the background of other components of small amplitude.

III. Recognition algorithm and its analysis

At the first stage, it is necessary to emphasize the peaks at the spectrum. In the proposed algorithm, the task is realized due to block merging, when the spectrum is divided into *N* intervals, in each of which the maximum value is calculated (Fig. 4, a). In the present work, *N* is set equal to 50, since in the vast majority of remote sensing systems the number of channels rarely exceeds that value. After that, a non-recursive averaging filter (*n* samples) is applied to smooth the spectrum fluctuations (Fig. 4, b). In the task, *n* is set equal to 3, which turns out to be sufficient to smooth out the existing fluctuations. As n increases, the peak is excessively blurred, which makes it difficult to detect, at lower n smoothing does not occur, which can lead to the appearance of side peaks. At the next stage, the sequence is converted to binary, for this, it is necessary to choose some threshold value, according to which the brightness elements will be cut off. Since the peaks in the task are strongly expressed relative to the general background, the median of the sequence was chosen as the statistics for calculating the threshold value. The result is shown in the Fig. 4, c. The flowchart of the first part of algorithm is shown in Fig. 6, a.

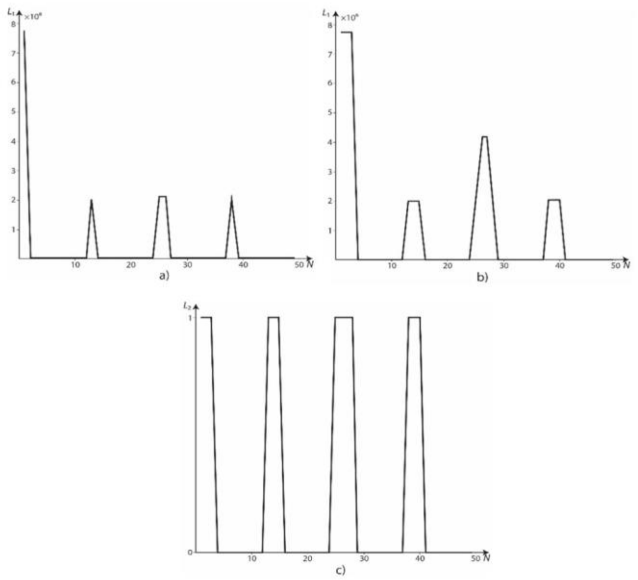

Fig. 4. The result of applying the first part of the algorithm to the Fourier image, shown in Figure 3, b: a) The result of maxima searching over N intervals; b) the smoothing result; c) the threshold processing.

From Fig. 4, c, it follows that the number of channels of the image exactly corresponds to the number of intervals with a logical zero. Accordingly, it is necessary to count such intervals. Counting is carried out in a cycle during which two one-dimensional arrays are formed, each of whose elements represents the length of either zero or unit interval. The flowchart of the second part of algorithm is shown in Fig. 6, b. It should be noted that in the spectra of real images there may side peaks due to the texture of the terrain, therefore, before the final calculation of the number of channels, such peaks have to be removed. The third part of the algorithm, which performs the removal of side peaks, operates as follows: if the array size interval per unit values corresponds to 1 or 2, then such array intervals per zero values must be combined. Values equal to 1 and 2 are selected based on the analysis of real images of the Earth from space, the principle of operation of the third part of the algorithm is shown in Fig. 5, The flowchart of the third part of algorithm is shown in Fig. 6, b.

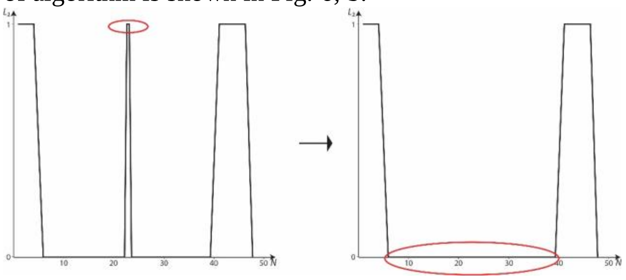

Fig. 5. The principle of the third part of the algorithm.

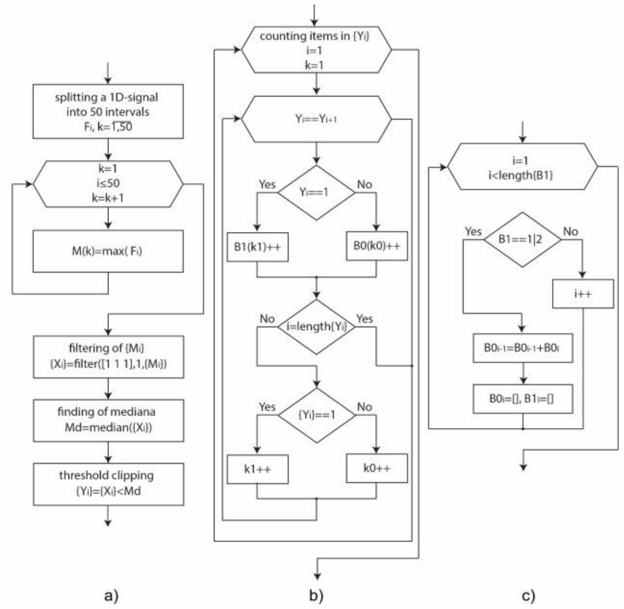

Fig. 6. The flowchart of the algorithm: a) the first part; b) the second part; c) the third part.

IV. THE RESULTS OF EXPERIMENT

The developed algorithm is implemented in MATLAB 18.b [6] and tested using images obtained from various remote sensing systems, including MODIS (2 and 5 channels) (Fig. 7) [7], SPOT (4 channels) (Fig. 8), Landsat-7 (6 channels) (Fig. 9) [9], AVIRIS (30 channels) [10], as well as data of DEM AcrGIS (2 channels). As follows from the figures, in all cases, the Fourier spectrum of a one-dimensional signal with the presentation format of multiband BIP data is divided into the number of intervals corresponding to the number of channels of the multiband image. For all used images, the algorithm showed the right operation, except when there was a high percentage of cloudiness over the image. In this case, there is no correlation between the different channels of the multidimensional image, and the quasiperiodic which is shown in Fig. 1–3 do not arise. It should be noted that such images usually are not of high value to the researcher, and the proposed algorithm can be used, including for automated search of the indicated moments: if for all three types of storage of multidimensional data, the spectrum of the Fourier image is divided into one interval, then this indicates that the brightness values of the channel images are equal to each other.

TABLE I. SOME STATISTICAL PARAMETERS OF IMAGES

Remote sensing systems	No. of channels	Image size	Mean image bright.	Mean spect. bright.	Median spectrum brightness
MODIS/ 250m	2	9200×5416	9685	1.01×10^{11}	2.55×10^{8}
ArcGIS DEM	2	1800×3600	465	4.35×10^{8}	2.94×10^{7}
SPOT 4	4	3000×3000	144	3.90×10^{8}	1.63×10^{7}
MODIS/ 500m	5	4600×2708	8567	5.26×10^{10}	3.06×10^{9}
Landsat 7	6	512×512	23	1.26×10^{4}	1.71×10^{3}
AVIRIS	30	350×400	177	4.69×10^{4}	6.24×10^{2}

Since the median of the formed sequence acts as a threshold value during the algorithm operation (Fig. 6a), the question of the behavior of the median value for different remote sensing systems is of interest. Table 1 presents the value of the median and a number of other statistical parameters of the used images.

As shown in table 1, the median usually turns out to be an order of magnitude less than the mean value of the spectrum brightness. Therefore, if the median of the sample is used as the threshold value, then it can reliably cut off the peaks from the general background since it always turns out to be an order of magnitude smaller than the mean value, which is due to the pronounced quasiperiodicity, especially at BIP and BIL.

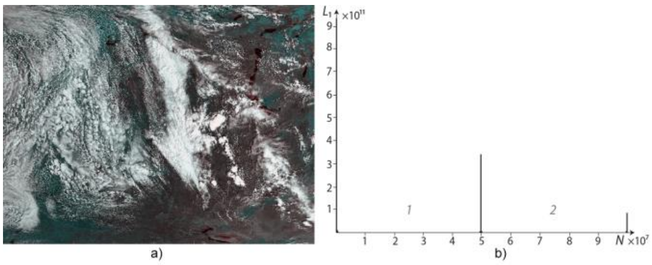

Fig. 7. a) Image fragment obtained by MODIS system (the two red and one infrared channels are shown); b) Fourier transform of the signal.

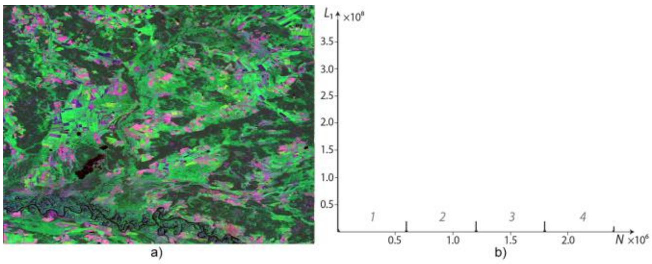

Fig. 8. a) Image fragment obtained by SPOT-4 system (the red, near infrared and infrared channels are shown);b) Fourier transform of the signal.

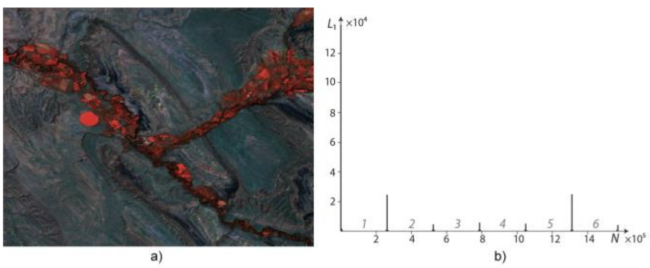

Fig. 9. a) Image fragment obtained by Landsat-7 system (the red, red edge and near infrared channels are shown); b) Fourier transform of the signal.

V. Conclusion

A method and algorithm for its implementation has been developed that automatically calculates the number of channels in multiband images stored in files of uncompressed formats with completely or partially lost metadata. This algorithm is sufficient for reliable identification of counting the number of channels into the BIP-format, which is one of the most common. The testing of the algorithm was verified on a series of real images of space systems for remote sensing of the Earth, in all cases, the number of channels was determined correctly, and the applicability limits of the developed algorithm are also indicated. The obtained results are going to form the basis of the work devoted to the automated recovery of damaged images using any of the three methods of multiband image storing with completely or partially lost metadata based on the Fourier spectrum analysis of the byte sequence.

Acknowledgment

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