ENERGY PHASES OF THE IMAGE ROWS AND THEIR APPLICATION

N.I. Murashko, S.V. Ablameyko

United Institute of Informatics Problems of the National Academy of Sciences of Belarus,
e-mail: *mni@newman.bas-net.by*, *abl@newman.bas-net.by*

Abstract: The model of grey scale image as a multivariate vector of energy phases of the rows, invariant to scaling and scene illumination, is proposed and investigated. The method of object detection on the non-uniformly scaled image sequence of an observable scene is considered. The correctness criterion of the digital methods of image scale change is adduced.

Introduction

Permanent control of environment by using remote sensing images requires effective techniques to detect the required objects and changes. Data volume used in this task is usually enormous and that leads to necessity of using powerful computers and is usually a time consuming. One of the main problems related to change detection methods based on the "difference image" lies in the lack of efficient automatic techniques for discriminating between changed and unchanged pixels in the difference image. Such discrimination is usually performed by using empirical strategies or manual trial-and-error procedures, which affect both the accuracy and the reliability of the change-detection process. There are several approaches for change detection in remote sensing images [1, 2]. In the paper [4], we proposed a method for detection of changes that is based on energy moments.

The image is formed by means of a video camera, which can move in space and change a focal length of the lens. An image scale modification of an observable scene can be carried out due to the focal length change of video camera lens or by approaching (or distance) it to the scene.

1. The energy of observation sites

The scene can be divided into elementary unitary sites, so called scene pixels, which we will name peakscenes. Each peakscene is a source of reflected light flux Φ_S, which is characterized by energy E_S. As a result, the observable scene will represent a matrix consisting of N_S peakscenes. Let the scene has uniform light illumination due to the falling on it light flux Φ_p. Then the light illumination of the scene is defined as follows $\Phi_S = \Phi_p / S_S$, where S_S - the area of peakscene. The average light illumination of all scene is equal

$$\Phi_C = \frac{1}{Ns} \times \sum_{s=1}^{Ns} \Phi_S$$

Let's choose the sizes of peakscene such, that their number coincide with the sizes of the image matrix, formed by a video camera at the minimal general scale $W^*_{\min}$, i.e. $Ns=M$. In this case the pixel of the image, received by a video camera, corresponds to the site of peakscene. If the reflection coefficient of peakscene in visible range is equal μ_s, then it radiates a light flux equal $\Psi_S = \mu_s \times \Phi_S$, which, after passing the distance h, gets on a photo detector of the video camera. It is well known from optics, that the light flux attenuates in inverse proportion to a square of the passed distance, i.e. the light flux Ψ_s^* will be received at the input of the video camera photo detector. The photo detector (optoelectronic converter) transforms the energy of the light flux to an electric signal $b_s = C_h \times \Psi_s^*$, where C_h - conversion coefficient of energy. As a result there is an unequivocal conformity of the observable scene and the received image.

Let's choose on the observable scene an area of interest of rectangular form, to which the fragment of the image corresponds. The sizes of the area of interest should be such that, in case of enlargement, it will not leave a vision field of the video camera. Let's consider two variants of enlargement of the area of interest.

The scene is observed by means of a video camera with a variable focal length. In this case the distance h remains constant. At increasing the scale in W_m=n times, n pairs of identical pixels will appear in the row of the image. Thus the average brightness of the row will not change and will be equal:

$$\bar{b}(n) = \frac{1}{nNs} \sum_{j=1}^{Ns} \sum_{k=1}^{n} b_{j,k} \quad (1)$$

Here we have a uniform stretching of the row. At approximation of a video camera to the scene the distance h changes in n times. Therefore the light flux, which falls on n photo detectors increases in n times. As a result the brightness of pixels will not change. From it follows that the average brightness of the row will increase in n times:

$$\bar{b}(n^*) = \frac{1}{Ns} \sum_{j=1}^{Ns} \sum_{k=1}^{n} b_{j,k} \quad (2)$$

Here the sign (*) indicates that the change of the scale is carried out as a result of video camera motion.

It is necessary to note, that in case of change of the image scale the sizes of its pixels change independently in row and column direction. At uniform enlarging of the image in n times the number of the rows and pixels in each row increases in n times.

2. The energy phase of the image row

The row of the real image is characterized by the center of energy moments (CEMR). [3, 4]. Physics of this method is as follows. The pixel of the row is represented as a point source of the light, i.e. the energy of the pixel is concentrated in its center. The distance between the neighboring pixels is equal to a conditional unit. And there will be always certain point L in the row, in which the energy moments of pixels, situated from both sides of it, are counterbalanced, i.e.

$$\sum_{j=1}^{L} (L-j) b_j^p = \sum_{j=l}^{Ns} (j-L) b_j^p . \quad (3)$$

Here Ns - odd number. If the row has even number of pixels, then it is supplemented with pixel, having zero brightness.

Decision of the equation (3) has the following type:

$$L = \frac{\sum_{j=1}^{Ns} j \times \left(b_j - \overline{\Delta b}\right)^2}{\sum_{j=1}^{Ns} \left(b_j - \overline{\Delta b}\right)^2}, \tag{4}$$

where $\overline{\Delta b_j} = \frac{1}{Ns}\left(\sum_{j=1}^{Ns} b_j(t) - \sum_{j=1}^{Ns} b_j(t-1)\right)$ - difference between the average values of the image brightness at time moments t and (t-1).

Formula (4) is inconvenient in the cases when the image scale changes or the form of its fragment differs from rectangular, as in this case, the numerical value of the center of energy moments of the row changes, although the center of energy moments remains invariable. It is possible to remove the mentioned disadvantage due to the application *of the energy phase of the row (EPIR).*

The row of the image can be characterized as one full harmonious fluctuation modulated by the sequence of brightness of pixels $B\{b_1, b_2, \ldots, b_{S+1}\}$.. In this case the image of the rectangular shape is represented as a sequence of fluctuations of one frequency, phase shifted concerning central pixel. Fluctuation period is equal to the number of pixels in the row, and the amount of fluctuations - to the number of rows. Phase of fluctuations changes from $-\pi$ up to $+\pi$ radian and is equal to zero in the middle of the row (pixel with coordinate (Ns-1)/2+1).

According to (4) it follows, that the CEMR can vary from 1 up to Ns, i.e. can change concerning a central pixel. Let the energy phase of the row defines as

$$E_w = \pi \times \frac{L - [(Ns-1)/2 + 1]}{Ns}. \tag{5}$$

Let's substitute the value L at p=1 in (5). As a result we'll receive:

$$E_w = \frac{\pi}{Ns} \times \frac{\sum_{j=1}^{Ns} j \times b_j}{\sum_{j=1}^{Ns} b_j} - \frac{\pi}{2}\left(1 + \frac{1}{Ns}\right) = \frac{\pi}{Ns} L - \frac{\pi}{2}\left(1 + \frac{1}{Ns}\right) \tag{6}$$

Equation (6) contains variable and constant components for a given length of the row Ns. At Ns>> 1, that is true for the full picture (Ns> 500), we'll receive:

$$E_w = \frac{\pi}{Ns} \times \frac{\sum_{j=1}^{Ns} j \times b_j}{\sum_{j=1}^{Ns} b_j} - \frac{\pi}{2} \tag{7}$$

From (7) the properties of the energy phase of the row follow:

Property 1 If energy phase of image row (EPIR) is equal to zero then all the pixels of the row have the same brightness or it is symmetric concerning an average pixel.

Property 2 Two rows will be identical if their non-zero energy phases coincide.

Property 3 At rotatory reflection of the row (turn on 180°) the EPIR value changes a sign on opposite, keeping an absolute value.

EPIR diagram for the initial and rotatory reflected around the central column images are shown in fig.1.

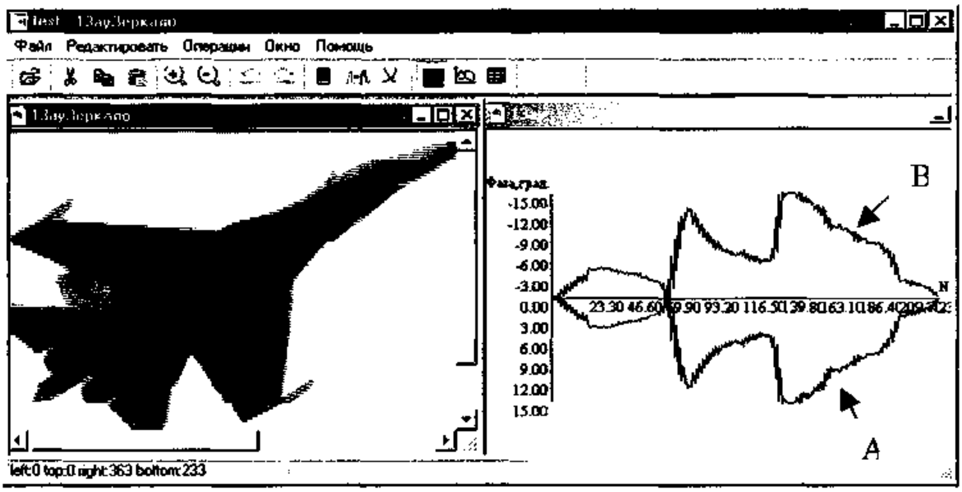


Fig.1 Distribution diagrams of the energy phases of image rows: a) initial image, b) EPIR diagrams. A - EPIR diagram for the initial image, B – for rotatory reflected image

3. Invariance of the energy phase of the row to the change of the image scale

Let's consider a connection between the energy phases of the rows of the initial and scaled images. At enlargement of the image in n times the length of the row will increase also in n times. Let n =1, 2, 3, 4, ... Then every pixel will be transformed into the group, consisting of n pixels, having the same brightness. The length of the row will contain n×Ns pixels. Let's calculate the center of energy moments and the energy phase of the enlarged row for a fixed video camera with a changeable focal length and for the moveable video camera.

As it was mentioned above, the increasing of the scale by changing the focal length of a video camera in n times does not reduce average brightness of the row. For simplicity of calculations let's replace each of the pixel groups with their centers of "gravity". Thus the center of the first group will be displaced on a distance r = (1+n)/2 from the beginning of the row and the distance between centers of the groups will be equal n. In this case we'll receive:

$$L_n = \frac{\sum_{j=1}^{Ns} nJ \times b_j}{\sum_{j=1}^{Ns} j \times b_j} + \frac{n+1}{2} = \frac{n+1}{2} + n \times \frac{\sum_{j=1}^{Ns} j \times b_j}{\sum_{j=1}^{Ns} b_j} = \frac{n+1}{2} + n \times L \quad (8)$$

If the enlargement is carried out by approaching of video camera to an observable scene, then each of n pixels of the group keeps the initial brightness. In this case we'll have:

$$L_n^p = \frac{\sum_{j=1}^{Ns} n \times j \times n \times b_j}{\sum_{j=1}^{Ns} j \times n \times b_j} + \frac{n+1}{2} = \frac{n+1}{2} + n \times L \quad (9)$$

From (8) and (9) follows, that the position of the center of energy moments of the row does not depend on the way of obtaining of the enlarged image. For calculation of the energy phases of the image row let's substitute the value of the center of energy moments of the row from (9) in (6) taking into account, that the number of pixels of the enlarged image is equal $N^* = n \times Ns$. As a result we'll receive:

$$E_W(n) = \frac{\pi}{Ns} L - \frac{\pi}{2}\left(1 + \frac{1}{Ns}\right). \tag{10}$$

Comparing (10) and (7), we come to a conclusion that *the energy phase of the image row at the correct change of the scale does not change*. This statement refers to both integer and fractional scale coefficients. Phase value of the row remains invariable in case of the correct enlargement both for grey scale and for color images. Thus the phase values of a color and grey scale row are differed. It is connected with the error calculations of energy of the color image row which remains invariable in case of scale change.

4. Inspection of the correctness of image scaling

During the analysis of an observable situation an overlapping procedure of non-uniformly scaled images is used. Thus, a various accuracy of scaling, depending on methods of image identification is required. Let's accept a measure of image similarity to its reference as a correctness of image scaling. There are various methods of definition of image similarity, among them there are correlation methods, which are most frequently used. Let's consider an estimation of the image scaling correctness, using the energy phases of the rows.

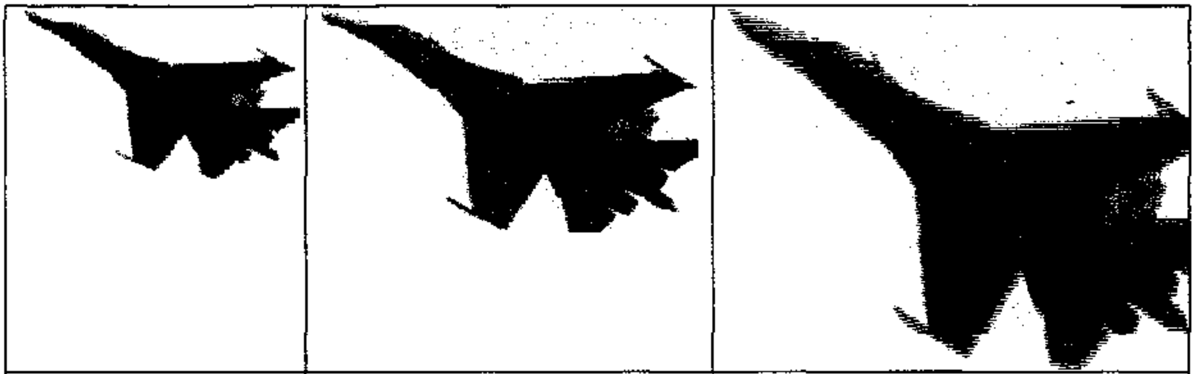
In case of computer image scaling the energy distribution in the rows should not vary, as the energy phases of the rows should remain in the given limits. At the decision of applied problems the accuracy of calculation depends on criterion of scaling correctness.

Inspection of scaling correctness is estimated by comparison of the values of energy phases of corresponding rows on the enlarged and initial images. With this purpose the sequences of energy phases of the initial $\Phi w(n) = \sum_{i=1}^{m} Ew(i)$ and scaled $\Phi^* w(n) = \sum_{i=1}^{m} E^* w(i)$ images are calculated. A correlation coefficient of the mentioned sequences is calculated as ratio of their covariation to the product of their standard deviations.

To define the correctness of linear scaling it is sufficient to compare the values of the energy moments of corresponding rows and columns, intersecting the central image pixel.

Conclusion

The model of the image of an observable scene as phase space of energy features is offered. Distribution of the energy phases allows to extract informative features of the observable object. A plane as an object of observation is shown in fig. 2. At approaching of the plane its sizes and surrounding background are changing. The phase space has a unique property of invariance to object scale and illumination of the scene. At consideration of the image sequence of an observable scene it is possible to note independent fluctuations of phase values of lines and columns. These fluctuations characterize a space of the image informative features.



ρ_k=0,988	ρ_k=0,990	ρ_k=0,998

Fig. 2 The plane on different distance from the observer. Image correlation coefficients between object and reference are shown in the table.

References

[1] Xiaolong Dai, Automated change feature extraction systems in remote sensing, Proc. SPIE, 566-576, vol.3460, 1998.

[2] Morisette, J.T., Khorram, S., An introduction to using generalized linear models to enhance satellite-based change detection, Proceedings of International Geoscience and Remote Sensing Symposium, 1769-1771 vol.4, 1997

[3] Н.И. Мурашко Автоматическое обнаружение изменений на динамических изображениях// Цифровая обработка изображений.- Минск: Ин-т техн. кибернетики НАН Беларуси,2001.С 93-103.

[4] N.I. Murashko, S.V. Ablameyko Detection of Situation Changing in Remote Based of Energy Moments// Pattern recognition and information processing - Minsk, 2001.- P.69-76.