



THE APPLICATION OF THE COVARIANCE METHOD ANALYSING THE DIGITAL IMAGES OF LAND SURFACE

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Abstract. Accuracy issues of identification possibilities and analyzing digital images of land surface are examined using a covariance method. Digital images received using remote access methods are treated by the computer programmes developed in the *Matlab 7* software package environment. The paper investigates the opportunity to automatically compare two digital images of fragments and determines the interdependence of comparable images. The interdependence of two images is verified according to the calculated values of the correlation coefficient. Considering a more absolute value of the correlation coefficient between compared digital images, dependency is higher and vice versa. Such method could be applied to long-term monitoring in order to control the temporal evolution of selected images.

Keywords: land cover changes, covariance function, comparison pixel, digital images.

1. Introduction

The determination and fixation of land cover changes emerging under the impact of different factors (human activities, erosion etc.) require plenty of time and additional resources. However, it is important to fix (observe) these variations, because only under effective observation of on-going changes in land cover, the decay of land resources and landscape destruction may be prevented. In consideration thereof, different methods of fixing and observing corresponding changes in land cover, including photographing, are developed (Millington *et al.* 2009).

It is important to identify locations where changes in land cover take place and determine factors causing them (e.g. rapid water erosion is the main agricultural problem worldwide), thus applying different control principles.

The major part of data about land cover (its changes) are received remotely – from aerial photos and satellite images processed and analyzed applying different GIS technologies. Geographical information systems (GIS) are an effective tool for various analyses related to environment protection, and therefore may be successfully applied for determining the intensiveness of possible erosion (Šurda *et al.* 2007).

The article describes a low-cost method that also may be applied for long-term monitoring – the observation of changes in the selected objects (e.g. stream chan-

nels) in time. There is a possibility of determining the similarity (dependence) of two digital images created in different time applying Pavkor.m program (Skeivalas, Kizlaitis 2009) switched into the automated mode. The interdependence of images is assessed according to correlation coefficients estimated using the program; their value may vary from -1 to 1 . The best equivalent is received when the correlation coefficient equals to 1 (Ruzgienė 2008; Linder 2003).

The objective of the paper is to identify digital images (determine their matching) applying the theory of covariance.

Research objects are digital orthophotographic colour maps, scale M1:10 000, drawn in 2006 and 2009 in the same locality.

The details of orthophotographic maps are defined in picture elements – pixels (Sužiedelytė-Visockienė, Žalnierukas 2004). Identifying digital images by using mathematical operations, a spatial position of digital image pixels, defined by the number of lines and columns, is converted into a spatial area representing the frequency of the colour wave. With reference to it, the coordinates of every pixel of a digital image are defined taking into account the amplitude of the oscillations of the colour with corresponding frequency and the stage, and vice versa, pixel coordinates may be identified according to the amplitude of the oscillations of the known frequency and in accordance with the stage (Skeivalas,

Kizlaitis 2009). Different mathematical operations and image transformations applying to image data are performed.

The article analyzes the identification of digital images and determination of changes in land cover applying the correlation method. The paper assesses whether the visual quality of digital images – brightness (contrast) – influences the results of identifying these images.

2. Method

For the analysis of identifying digital images, we will refer to the theory of covariance. A correlation coefficient of two random variables (pixels) X and Y is calculated according to the known formulas for mathematical statistics. One of them is applied when a sample set of the corresponding volume is used (Skeivalas 1999, 2001):

$$r_{xy} = \frac{K_{xy}}{m_x m_y}, \quad (1)$$

where K_{xy} – covariance influence; m_x, m_y – the influence of standard deviation.

Covariance influence under the existing formula for sample members is as follows:

$$K_{xy} = \frac{1}{n} \sum_{i=1}^n x_i y_i - \bar{x} \bar{y}, \quad (2)$$

where x_i, y_i – two samples of respective members; \bar{x}, \bar{y} – sample averages; n – sample volume. Sample members are the values of the pixel colour.

The influence of standard deviation is calculated using the following formula:

$$m_x = \sqrt{\frac{1}{n} \sum_{i=1}^n x_i^2 - \bar{x}^2}, \quad (3)$$

$$m_y = \sqrt{\frac{1}{n} \sum_{i=1}^n y_i^2 - \bar{y}^2}. \quad (4)$$

Following the available data on the vector of digital image pixels, the influence of the covariance matrix is calculated (Bručas *et al.* 2007) as:

$$K_{XY} = \frac{1}{(n-1)} \delta X^T \delta Y, \quad (5)$$

where δX and δY are the centred matrices of two digital image pixels.

$$\delta X = X - MX, \quad (6)$$

$$\delta Y = Y - MY, \quad (7)$$

where X, Y – is a pixel matrix (an array) of a certain digital image; MX – is a matrix of vector averages in matrix X; MY – is a matrix of vector averages in matrix Y.

The scale of every point of digital images slightly differs. Therefore the influence of the scale on the covariance is negligible because the frequency of the colour wave of a single pixel remains the same, i.e. irrespective

of its scale. The width of the selected fragments in digital images may vary in line with the number of pixels.

3. Results and their analysis

A comparison of two images has been performed using *Pavkor.m* program developed applying an operator of *Matlab* programming (Skeivalas, Kizlaitis 2009) offering unlimited opportunities for the development and analysis of black-and-white as well as colour digital images using different functions of image processing (Pupeikis 2008).

When using *Pavkor.m* program, two digital images or fragments of one digital image are compared, covariance and correlation coefficients are determined. In this case, two fragments of digital images are used where one fragment is taken from an orthophotographic map, scale M1:10 000, made in 2009 (TIFF format) and another – from an orthophotographic map, scale M1:10 000, produced in 2006 (TIFF format).

Along with the application of *Pavkor.m* program, four versions of analysis have been performed (see Fig. 1):

For comparison purposes, numeric fragments of certain parts in the form of rectangular arrays were formed. The pairs of the fragments of compared digital images and calculated correlation coefficients are shown in Fig. 1.

The results of four examined versions employing *Pavkor.m* program in the spectrum of three colours (RGB) are shown in Table 1.

When using *Pavkor.m* program, a matrix of correlation coefficients corresponding to the vectors of the image pixels was developed. The analysis of every version has shown that the highest correlation coefficient (r_{\max}), average (r_{vid}) and average absolute correlation coefficients ($|r|_{\text{vid}}$) have been estimated according to the full spectrum of colours (see Table 1).

Table 1. Four versions of r_{\max} , r_{vid} and $|r|_{\text{vid}}$ values calculated using a three-color spectrum

Versions	r_{\max}	r_{vid}	$ r _{\text{vid}}$
1	1	0.18877	0.21822
2	1	0.10758	0.19176
3	1	0.79254	0.79254
4	1	0.051287	0.14151

Pavkor.m program was also used for estimating correlation coefficients of one pair (Fig. 1a, b) of image fragments in separate spectra of colours (R, G and B). The estimated correlation coefficients in case of selecting a red (R), green (G), blue (B) or three-color (RGB) spectrum are provided in Table 2. Differences between them are graphically shown in Fig. 2.

The obtained results showed that correlation coefficients estimated in the spectrum of three colours (RGB) and those selecting either a red (R), green (G) or blue (B) spectrum slightly differed. Differences in correlation coefficients do not exceed accuracy limits of estimating correlation coefficients, i.e.:

$$m_r = \frac{(1-r^2)}{\sqrt{n}} = 0.005.$$

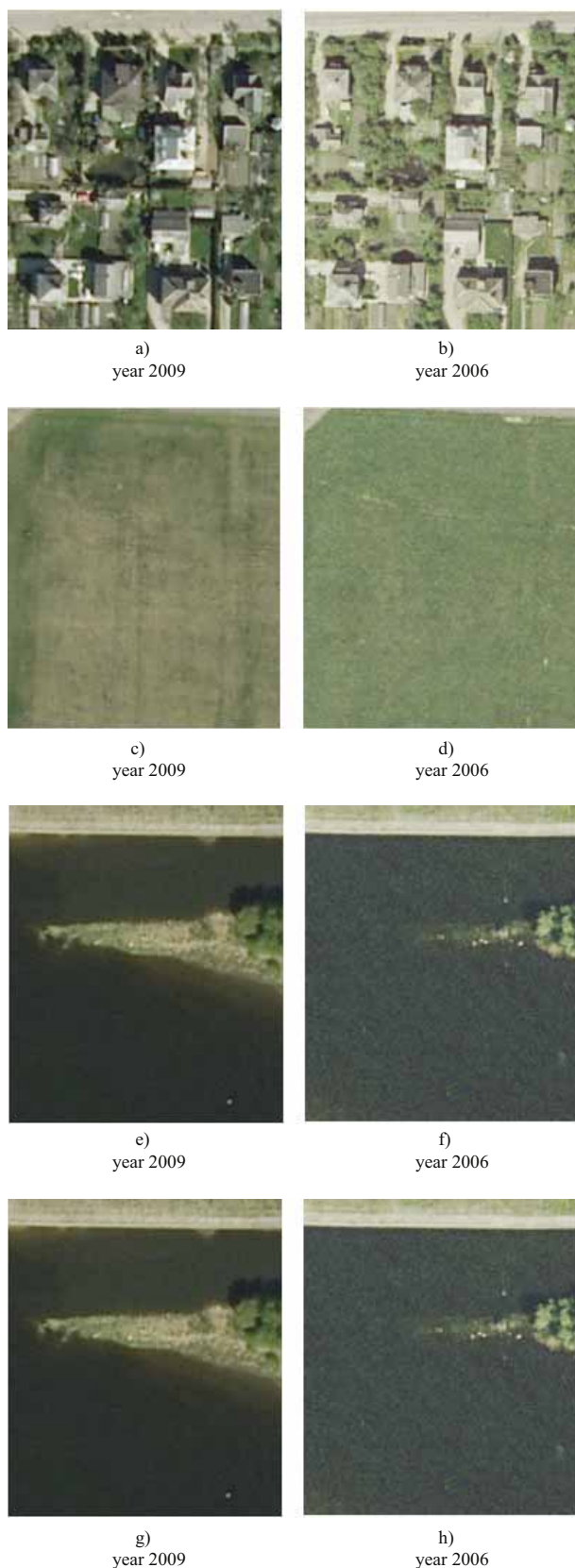


Fig. 1. The clips of orthoimagery maps made in 2009 and 2006 and used for analysis (investigation)

It means that when using *Pavkor.m* program, correlation coefficients may be estimated precisely enough for selecting only a single colour spectrum (R, G or B). It is useful when large digital images (covering large areas of

high resolution and requiring much computer memory) are compared using the program because after selecting a spectrum of three colours (RGB), estimations of their correlation coefficients require plenty of time. If only one colour spectrum (R, G or B) is selected, correlation coefficients are estimated considerably faster.

Table 2. The values of the correlation coefficients calculated in the R, G, B and RGB colour spectrums

Colour spectrum	Correlation coefficient	Results
1	2	3
R	r_{max} r_{vid} $ r _{vid}$	1 0.19948 0.23055
G	r_{max} r_{vid} $ r _{vid}$	1 0.17732 0.20893
B	r_{max} r_{vid} $ r _{vid}$	1 0.19284 0.21811
RGB	r_{max} r_{vid} $ r _{vid}$	1 0.18877 0.21822

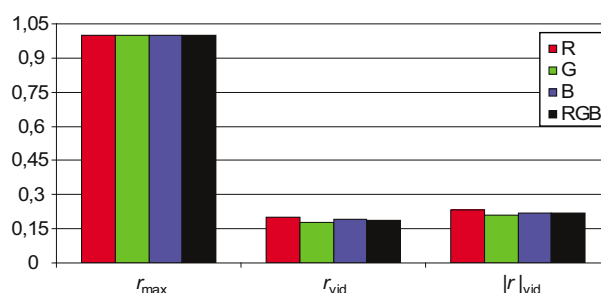


Fig. 2. A comparison of correlation coefficients calculated for different colour spectra

The tensors of the interdependences of the pairs of image clips generalized according to the RGB colour spectrum are assessed applying the matrices the correlation coefficients. They equal to:

$$K_{1version} = \begin{vmatrix} 1 & 0.48507 \\ 0.48507 & 1 \end{vmatrix},$$

$$K_{2version} = \begin{vmatrix} 1 & 0.68859 \\ 0.68859 & 1 \end{vmatrix},$$

$$K_{3version} = \begin{vmatrix} 1 & 0.80261 \\ 0.80261 & 1 \end{vmatrix},$$

$$K_{4version} = \begin{vmatrix} 1 & 0.4328 \\ 0.4328 & 1 \end{vmatrix}.$$

The produced matrices show that the weakest correlation (weak dependence) makes +0.48 and +0.43 and appears in case of the first and fourth version respectively, i.e. between the image fragments of a built-up area (Fig. 1a and b) and those of forest images (Fig. 1g and h). The results also indicate that similarity (concurrency) of colours in compared image fragments is very weak. Thus, it may be asserted that differences in land cover (of a locality) in these image fragments are clear. The highest dependence is observed in Version 3 (Fig. 1e and f), whereas correlation equals to +0.8 which means these images contain minor changes in local situations.

Figs 3–6 graphically show variation in correlation coefficients estimated comparing the first three pixel lines of fragments. One may freely choose the number (interval) of compared pixel lines.

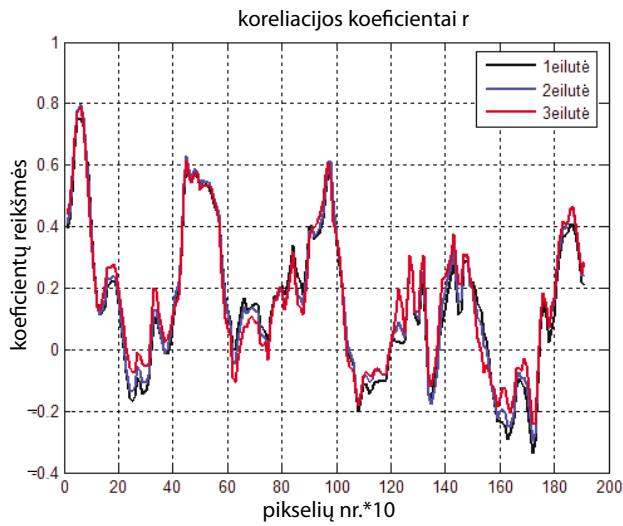


Fig. 3. Variation in correlation coefficients estimated comparing the first three pixel lines of the images of the built-up localities (Fig. 1a and b)

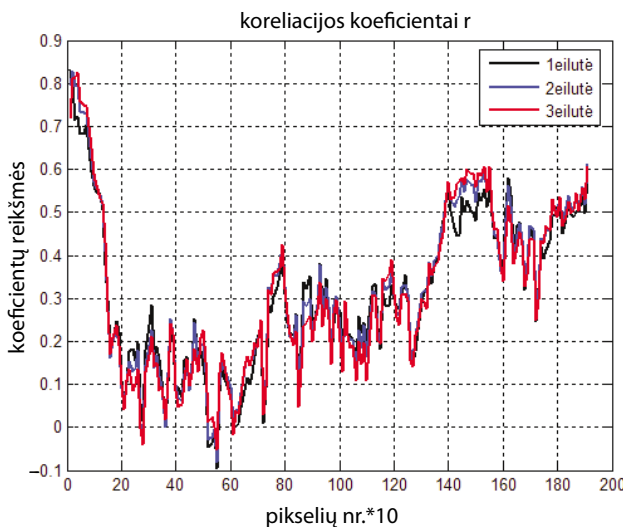


Fig. 4. Variation in correlation coefficients estimated comparing the first three pixel lines of the images of the arable land (Fig. 1c and d)

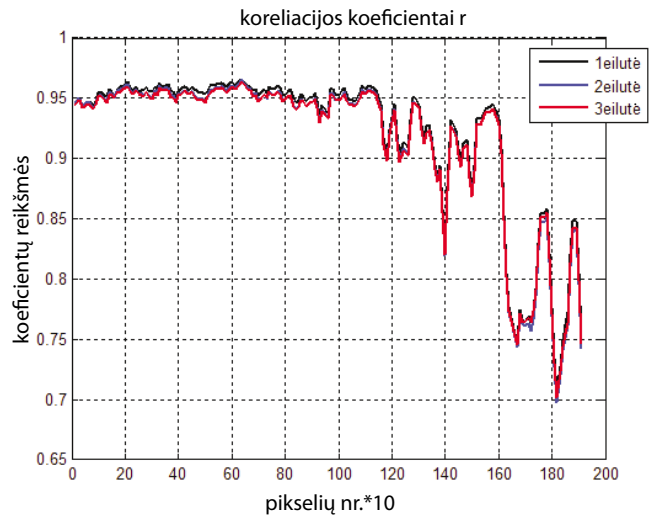


Fig. 5. Variation in correlation coefficients estimated comparing the first three pixel lines of the images of water coast (Fig. 1e and f)

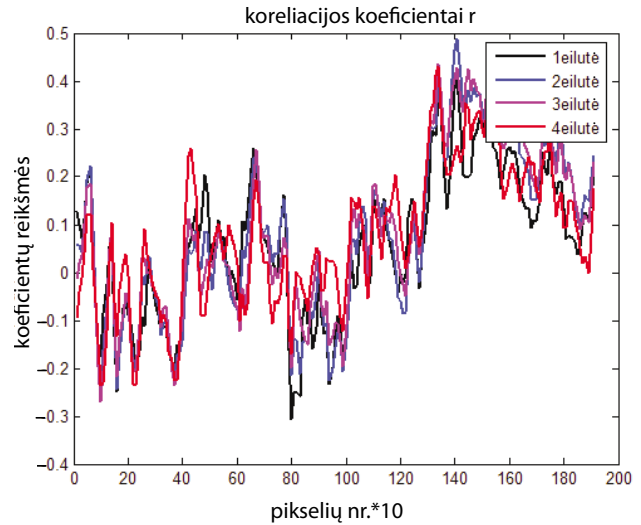


Fig. 6. Variation in correlation coefficients estimated comparing the first three pixel lines of the images of forest localities (Fig. 1g and h)

Following the assessment of the received results shown in Figs 3–6, it may be affirmed that the estimated (within the RGB spectrum) correlation coefficients vary from -0.7 to +0.97.

The most significant difference (the lowest concurrence) between compared first three pixel lines is shown in Fig. 6 where the first three lines of the image fragments of the forest locality are compared (Fig. 1g and h). The variation interval of correlation coefficients is between -0.33 and +0.5 which means that the biggest changes in the situation can be noticed between compared pixel lines.

The slightest difference (the highest concurrence) is displayed in Fig. 5 showing the first three lines of water coast fragments (Fig. 1e and f). The variation interval of correlation coefficients is from +0.7 to +0.97 which points to the strongest similarity in these compared pixel lines.

The conducted experiment has estimated the influence of the visual brightness (contrast) of digital images on the results of image identification.

With the help of *Pavkor.m* program, two image fragments of the same built-up area and the same contrast have been compared (Fig. 7a and b). Correlation coefficients have been estimated as $r_{\max} = 1$, $r_{\text{vid}} = 0.037\ 055$, $|r|_{\text{vid}} = 0.18\ 350$.

In case of another version of using *Pavkor.m* program, two image fragments of the same built-up area having different contrast have been compared (Fig. 7c and d). The brightness (contrast) of one fragment (Fig. 7c) has been altered using *Picture Manager* program (the selected options made +20 for 'brightness' and +8 for 'contrast'). After analysis, the following estimates of the correlation coefficient have been received: $r_{\max} = 1$, $r_{\text{vid}} = 0.036476$, $|r|_{\text{vid}} = 0.18366$.

Having compared the estimated correlation coefficients (r_{\max} , r_{vid} and $|r|_{\text{vid}}$), minor difference has been determined, i.e. the estimation accuracy of correlation coefficients is in compliance with set limits. The average accuracy of determining the correlation coefficient amounts to 0.002 (Skeivalas 2001)

$$m_r = \frac{(1 - r^2)}{\sqrt{n}} = 0.002.$$

Thus, the brightness (contrast) of digital images has no impact on identification results.

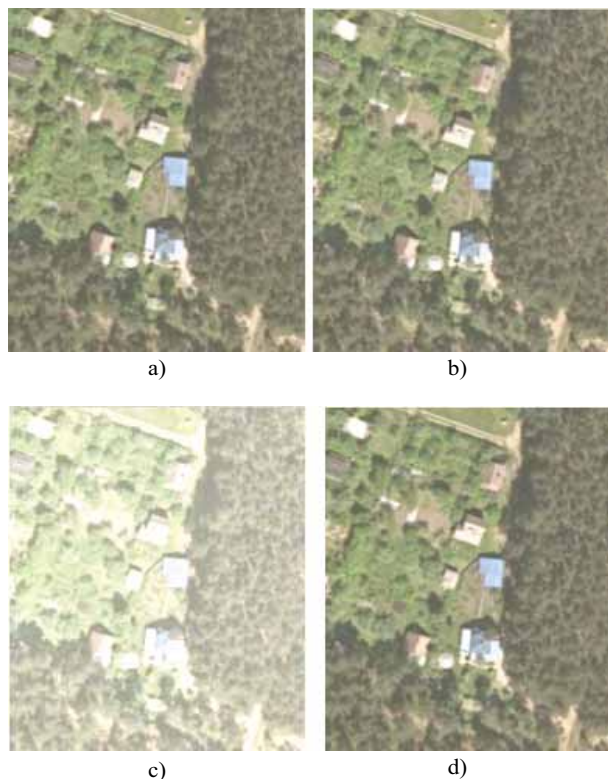


Fig. 7. Image fragments from the orthophotographic map designed in 2006 have been used for determining the visual brightness (contrast) of digital images

Hence, possessing the digital images of the same locality and made in different periods as well as using *Pavkor.m* program, the interdependence of images can be determined (similarity in the compared images can be assessed) automatically.

4. Conclusions

1. Research results have proved the possibility of performing the inter-identification of two digital images automatically assessing their inter-dependence according to the estimated correlation coefficients. A comparison of the images has disclosed that changes in the locality are minor when the correlation coefficient is close to 1. The provided method is an effective tool for performing different analysis of environment protection when received results may be applied determining (observing) the variety of changes in land cover (e.g. different land tenures, coasts, etc.).
2. After selecting the corresponding pixel lines, changes in a particular locality (pixel lines) may be determined. The results are graphically presented (Figs 3–6). Moreover, there is a possibility of determining changes in land cover in digital images.
3. The correlation coefficients estimated using a three-color spectrum (RGB) do not differ from those estimated using a single colour spectrum (red (R), green (G) or blue (B)). So, only one colour spectrum is sufficient for estimating coefficients.
4. The visual quality of digital images – brightness (contrast) – does not have an impact on the results of image identification.

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