CORRELATION OPERATOR FOR EDGE DETECTION

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1. INTRODUCTION

When performing the digital processing of remote sensing data /further as RS data/, it becomes often necessary to detect the boundaries between two objects, in other words to enhance the outlines of individual objects. This task is usually solved by applying one of the edge detection techniques. An edge is usually defined as a discontinuity of certain image atribut, in most cases of the brightness level. Individual objects in the image differ each other mainly by this atribut. Locating the boundary lines of individual objects by the edge detection can be completed only approximately and partially, because every detected edge is not inevitably a part of the object´s boundary, and the whole boundary line need not always be detected as an edge.

Currently, numerous techniques of edge detection in grey-level images have been theoretically developed and practically verified. The objects differ usually by grey-level values and the techniques are mostly based on computing various differential operators. The methods descriged in [1], [2], [3] are more or less complicated, require more or less computing time and perform with higher or lower accuracy.

In comparison with grey-level images significantly more coded information can be found in color and multispectral images. The techniques of their processing including edge detection are however much more complicated. Now, an image point is not determined by a sole number, but it must be assigned by the N-dimensional vector. For simplicity, we shall further consider a widely known image model, commonly expressed by components R, G, B. All following considerations can be generalized with a certain inaccuracy, for multispectral images. Let the values of brightness-level of individual image points be f_R, f_G, and f_B. Using these values, the values of r, g, and b for any point can be defined [3], [4].

$$r = f_R/(f_R+f_G+f_B) \tag{1}$$

$$g = f_G/(f_R+f_G+f_B) \tag{2}$$

$$b = f_B/(f_R+f_G+f_B) \tag{3}$$

Their importance lies first of all in the independence on illumination of the whole sensed scene. The equations (1), (2), (3) can be rewritten in the reverse form:

$f_R = r.y$ (4)

$f_G = g.y$ (5)

$f_B = b.y$ (6)

where $y = f_G+f_R+f_B$

It can be affirmed, that the values f_R, f_G and f_B for a certain pixel are determined by values r, g, b independent on illumination, and by the value y /luminiscence/ which depends on the scene illumination. From eq. (4) - (5) we come to conclusion that the change of pixel´s illumination will result in multiplicative change of grey-level only by a constant, which value would be the same for every component. In the case of logarithmically sensed image the products in eq. (4) - (6) are replaced by sums, usually more convenient for further processing. Now, the effect of illumination can be expressed in a simpler way - by an additive constant. The above mentioned model does not present evidently the only possible way of color image representation. In the study [5] other types of models frequently used for color image processing, are introduced. General definition of an edge - as a discontinuity of any image atrigut - can be applied in all previously mentioned cases. However, the definitions may differ depending on the image type and the form of its representation. That is to say, how to define the discontinuity in the N-dimensional space?
One of following versions is commonly used:

a/ To define the distance in the chosen symptom area /i.e. in the area, determined by individual components of the image color representation/. Then the edges are searched in the picture as a group of image points which - relating to above mentioned distance - significantly differ from any of their neighbours.

b/ The symptom area is transformed to another base or into a simple symptom and the edges are detected by a chosen grey-level method.

c/ The edges are detected separately in image components. Resulted edges are then composed from all image components with the use of any proper method [6].

2. CORRELATION EDGE DETECTOR

Some disadvantages of above mentioned methods led to the design of a new method - edge detection by the correlation - which has been developed, algorithmized, progremmed and verified at the authors laboratory, using various sets of data. Following ideas have been considered:
When passing from one pixel to its neighbour inside a homogenous image area without edges, it is obvious, that such neighbours will be very similar. If one pixel from the pair lies on the opposite side of an edge, then such two points are dissimilar. The term "discontinuity" is here replaced by a rather vague word "dissimi-

larity". In order to make use of such property of the edge for its detection, the term "dissimilarity" needs to be explained exactly and quantified by a proper mathematical medel. A correlation coefficient showed to be convenient for this purpose. Let U and V be two neighbouring picture points of a multispectral image with the values $/u_1, u_2, \ldots, u_n/$ and $/v_1, v_2, \ldots, v_n/$ in individual spectral bands. Then the value of their correlation coefficient is given by the relation.

$$c(v,u) = \frac{\sum_{i=1}^{n}\left(v_i - \frac{1}{n}\sum_{j=1}^{n} v_j\right)\cdot\left(u_i - \frac{1}{n}\sum_{j=1}^{n} u_j\right)}{\sqrt{\sum_{i=1}^{n}\left(v_i - \frac{1}{n}\sum_{j=1}^{n} v_j\right)^2 \sum_{i=1}^{n}\left(u_i - \frac{1}{n}\sum_{j=1}^{n} u_j\right)^2}} \qquad (7)$$

It becomes obvious from considerations introduced in previous paragraphs that the eq. (7) can be used for the edge detection - - i.e. the detection of dissimilarity, even in our well known three-dimensional color space /R, G, B/. Let two neighbouring image points E, F have the grey-levels $/e_r, e_g, e_b/$ and $/f_r, f_g, f_b/$ in R, G and B bands. Furthermore, let these neighbours be of the same color. Then, considering the linear mode of digitalization, we can write the equations:

$$e_R = konst \cdot f_R \qquad (8)$$

$$e_G = konst \cdot f_G \qquad (9)$$

$$e_B = konst \cdot f_B \qquad (10)$$

Let´s further introduce the average values of grey-levels of these neighbours /i.e. average values of luminiscence/:

$$\bar{e} = (e_R + e_G + e_B)/3 \qquad (11)$$

$$\bar{f} = (f_R + f_G + f_B)/3 \qquad (12)$$

Substituting to the eq. /7/ we get:

$$c(E,F) = \frac{(e_R-\bar{e})\cdot(f_R-\bar{f}) + (e_G-\bar{e})\cdot(f_G-\bar{f}) + (e_B-\bar{e})\cdot(f_B-\bar{f})}{((e_R-\bar{e})^2+(e_G-\bar{e})^2+(e_B-\bar{e})^2)\cdot((f_R-\bar{f})^2+(f_G-\bar{f})^2+(f_B-\bar{f})^2)} =$$

$$= \frac{konst \cdot ((e_R-\bar{e})^2+(e_G-\bar{e})^2+(e_B-\bar{e})^2)}{konst \cdot \sqrt{((e_R-\bar{e})^2+(e_B-\bar{e})^2+(e_G-\bar{e})^2)^2}} = 1 \qquad (13)$$

An analogous equation could be derived for a pair of the same color neighbours, in the logarithmically digitalized image. Even in this case the correlation coefficient equals unity. It is evident, that the value of correlation coefficient need not be unity for the case of a pair of identically colored image points. The eq.(13) could be valid even for a pair of diferently colored neighbours in the logarithmically digitalized images. Value of c/E,F/ becomes again unity, even if these two points were not similar. They might be the part of an edge. Hence it follows, that the output of correlatin edge detector can be considered as a lower estimate of the edges really existing in the image. Numerous experiments carried out by the authors showed, the error originated in this way is not statistically significant. In spite of the fact, that the correlation is not the very exact means of expressing the measure of dissimilarity, the results obtained by its application seem to be more than satisfactory. Furthermore, it can be widely used for processing of multispectral images /e.g. from the Thematic Mapper/.

The algorithm of edge detection passes through the image and calculates for every pixel two values of correlation coefficients- -the first between this pixel and its diagonal neighbour and the second between the next following pixel and its diagonal neighbour. As a result of the edge detection the minimum of these two values is taken.

KOR/i,j/=min/c/f/i,j/,f/i+1//,c/f/i+1,j/,f/i,j+1/// (14)

where f/i,j/ is a vector of grey-level values in a pixel with coordinates /i,j/. The method of Robert's gradient works in grey-level images with the same environment. The correlation detector in this form can be considered as its modification for multispectral images. It is easy to devise its other forms representing a modification of other known operators.

Remarks: It is advantageous for the programming to compute rather the values of c^2/U,V/.sign/c/U,V// instead of merely c/U,V/, since the time consuming computation of square root is avoided.

3. CORRELATION COEFFICIENT AS A LOCAL TEXTURAL MEASURE

In the course of experiments with using the correlation coefficient for edge detection other possibilities of its use have been found, namely for computing the local textural measure.
The matter is following:

A fundamental information, coded in the image and used in its processing, is the spectral information, which charecterizes the reflectance of a sensed object for various values of the wavelength in every image point. This information is usually not sufficient for automated evaluation of RS images. There are many objects, not recognisable by their spectral properties only. That is why other symptoms e.g. the textural ones are used for automated interpretation, which characterize the surface versatility of individual objects. The simplest of such symptoms seems to be the local textural measure, expressed for every individual image point by values of previously chosen function of a given point environment. Most of textural measures used have been calculated in one spectral band only. This fact showed to be a source of certain problems. It was necesarry to express the textural property for each spectral band separately, but the dimension of the symptom space inadmissably increased. Other possibility is to choose limited number of spectral bands for this computation. The application of correlation operator represents an effective means of avoiding this problem. It remains to define the form of environment, over which the measure will be evaluated, and the form of a function for numerical description of the measure. The choice of environments and functions depends on the nature of problem being solved.

4. CONCLUSION

The experiments carried out proved that the use of correlation operator seems to be one of the effective methods of edge detection in color and multispectral images. In accordence with the authors experience best results of edge detection have been reached in satellite image data sets /e.g. from Thematic Mapper/. Some failures have occur in aerial multispectral photographs with high resolution of details. The correlation operator showed to be effective as a local texture measure for all types of image data in the Earth remote sensing.

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