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CHARACTERISTICS AND RECONSTRUCTION OF IMAGES FROM SNOW-COVERED MOUNTAINS

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Светослав Любенов, Гоце Тенчов. ХАРАКТЕРИСТИКИ И РЕКОНСТРУКЦИЯ НА ИЗОБРАЖЕНИЯ НА ПОКРИТИ СЪС СНЯГ ПЛАНИНСКИ ВЕРИГИ

Възоснова на моделни изследвания са получени основни характеристики на симетрични черно-бели изображения. Изследвани са модели на планински вериги покрити със сняг. Изследвано е поведението на такива изображения в процеса на изменение на разделителната способност на изображението. Цел на тези изследвания е да се предложи прост подход за получаване на изображение с по-висока разделителна способност от такова с по-ниска разделителна способност. Показано е, че при наличие на поне три изображения с различна, но по-ниска разделителна способност може да се получи задоволително изображение с по-висока разделителна способност. За тази цел се използва т.нар. еволюционна схема. Методът ще бъде приложен при изследване на снежната покривка на планински вериги.

Svetoslav Lyubenov, Gotze Technov. CHARACTERISTICS AND RECONSTRUCTION OF IMAGES FROM SNOW-COVERED MOUNTAINS

There are characteristics of black and white images which are acquired on the base of modern research models. The examinations are connected with mountain chains covered with snow. Such images behavior is studied by the process of changing the resolution of the image. The aim of these researches is to offer simple approach for acquiring image with greater resolution from one with lower resolution. It is shown that when tree images with different but lower resolution are presented, a new and better image with greater resolution can be obtained. For the purpose we use an evolutional scheme. The method will be applied to investigate the snow cover of mountain chains.

***Keywords*:** images processing, snow-cover
***PACS number*:** 42.30.W

1.INTRODUCTION

The water content and its dynamics in alpine basins are controlled by the snow content. In the last two decades broad information for mountain covered by snow is acquired by the satellite images [1,2,3]. This information requires high resolution images of mountain regions. Such images are not often available. A simple method for obtaining better resolution from series of low resolution images is under discussions in the present paper.

2. MAJOR CHARACTERISTICS OF THE INVESTIGATED IMAGES

We explore black and white images with maximum contrast. In this study, the brightness of the images B and the pixels can vary form 0 (black) to 1 (white). With these images, we aim to define the snow coverage of the researched mountain chain. We do not study the undertones of the colors in these images.

Now we introduce the following characteristics: image differences D, identity of two images I, and saturation of the image with snow S_S. Every cell of the image with coordinate: i,j is characterized by the brightness B_{ij}. Differential coefficient or only differentiation D_{ij} of a given cell is defined as follows:

(1) $$D_{ij} = | B_{ij} - \frac{B_{i-1,j} + B_{i+1,j} + B_{i,j-1} + B_{i,j+1}}{4} | .$$

The differentiation of the whole image is:

(2) $$D = \frac{1}{n^2} \sum_{i=1,\, j=1}^{n} D_{ij} \,,$$

where we admit that the image has square shape with n elements on each side. Essentially the differentiation gives idea of the degree of difference of neighbor elements.

The coefficient of identity or the relative identity I of two images with brightness B_{ij} and B^*_{ij} is defined as the follows:

(3) $$I = 1 - \frac{1}{n^2} \sum_{i=1,\, j=1}^{n} | B_{ij} - B^*_{ij} | .$$

The saturation of the image S_S gives us idea of the relative concentration of cells with maximum brightness:

(4) $$S_S = \frac{1}{n^2}\sum_{i=1,\, j=1}^{n} B_{ij}\ .$$

We examine several major types of images. They consist of 256 pixels. By decreasing the detail of the pictures, the whole number of pixels also decreases. We admit that the process is connected with averaging the brightness of every four neighbors of pixels. Then the number of pixels is decreasing with $2^2 = 4$. This means that consecutiveness of consolidation of the image is 256→64→16→4→1 pixels. We study the following symmetrical images, which are marked with *A*, *B*, *C*, and *D* (Fig. 1). The parameter S_S is in brackets.

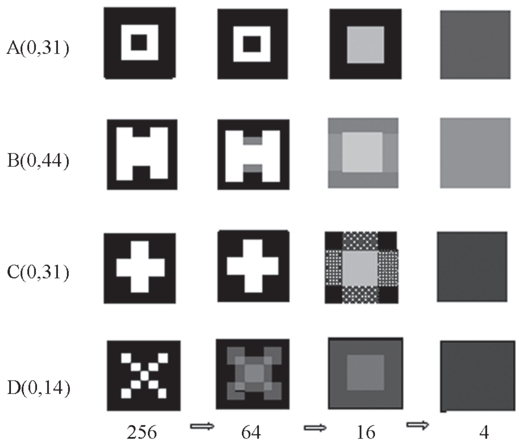

Fig. 1

In the process of consolidation it can be noticed that with transformations from 256 to 64 pixels, the image does not change essentially its characteristics (except *D*). When the details of the field are 16 pixels, the tree images are similar, and when we have four pixels, the images are losing their detail.

The changeability of *D* and *I* and the connectivity between them in these images are shown on Fig. 2 and Fig. 3.

The common tendency of the results (see Fig. 2), shows that decreasing the number of the pixels representing the image leads to consequently decreasing the differentiation. When the resolution is high (64 and 256 pixels) the differentiation is practically preserved.

Fig. 3 represents the common tendency of variation in the identity of image with given resolution in connection with the image with maximum details. This is the image with of 256 pixels resolution. Logically the identity

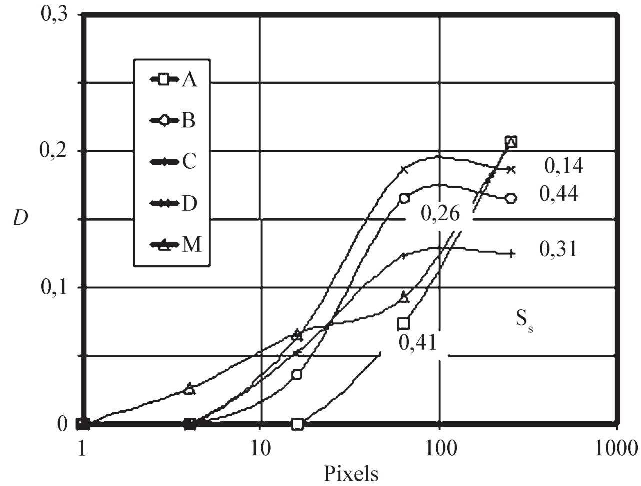

Fig. 2

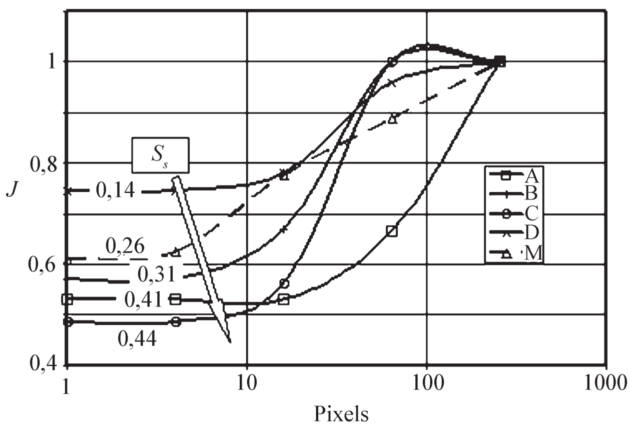

Fig. 3

of the image decreases with decreasing the number of pixels that form the picture. The identity of the images *B*, *C*, and *D* is not essentially changing with transitions from 256 to 64 pixels, while the changes in image A are sensible. Similarly, we can perceive a tendency of decreasing the identity when increasing the saturation Ss in low resolution and the opposite tendency with high resolution.

On Fig. 4 we have juxtaposed the parameters *I* and *D*. The common tendency is in decreasing the identity of the image with the original one (with 256 pixels) when the differentiation of the image also decreases. The saturation S_S also influences this dependency, and this influence is different in the areas of high and low differentiation of the image.

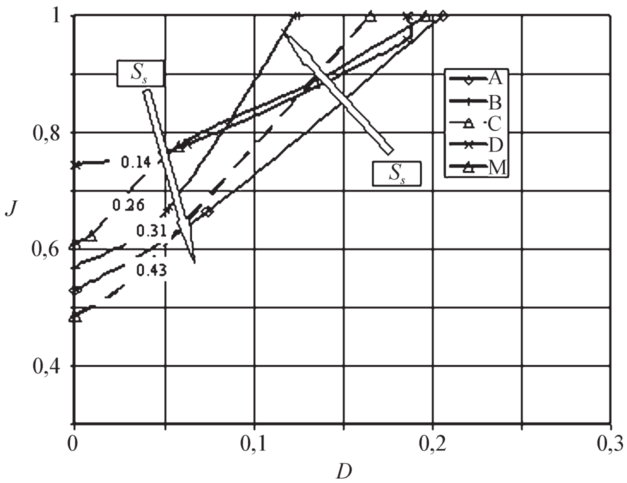

Fig. 4

3. INVESTIGATED MODEL

A model of a mountain chain has been made (Fig. 5) with asymmetrical shape, covered by snow and with parameter $S_s = 0.26$. When we transform an image from 256 to 64 pixels, the unsymmetrical image starts to change, but is keeping some information about the object.

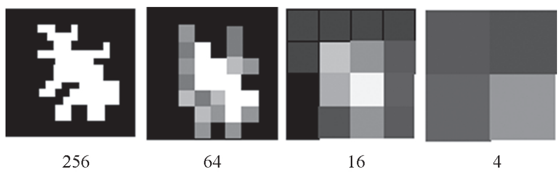

Fig. 5

When we decrease the resolution to 16 pixels the new image is different from the symmetrical images, but there we have a new resembled element-square contour. The image transformed to 4 pixels practically has 3 colorless and one gray square. The parameters of this image are showed on Fig. 2, Fig. 3, and Fig. 4, where the corresponding values are designated with "*M*". We can see that the characteristics of the mountain chain are adjusted to the common tendency of the symmetrical images, when we transform it from one image to another.

The process of reconstruction can pass through several stages. We will focus upon the most appropriate ones in our case. We examine the process of obtaining images with 256 pixels resolution from image with 64 pixels. We use the task from Fig. 5*b* to acquire figure with maximum similarity to the image on Fig. 5*a*. We have to obtain black and white image with maximum contrast. With this appearance, the image from Fig. 5 is characterized with identity $I = 0.78$. We convert the image to a one with maximum contrast using a processing condition like *IF(*B_{ij}*>q then* B_{ij}=1.0) with the following meaning: "if the brightness of the pixel is $B_{ij} > q$, then B_{ij} accepts maximum brightness 1, otherwise its brightness is 0". Then $I = 0.81$. This simple transformation does not satisfy us. The performed different numerical experiments by us show that in this case, the best result is acquired when we apply the following transfer function:

$$B_{ij}^{*} = \frac{B_{i-1,j} + B_{i+1,j} + B_{i-1,j-1} + B_{i+1,j} + B_{i,j-1} + B_{i,j+1} + +B_{i-1,j} + B_{i-1,j}}{8}. \quad (4)$$

In this case we have $I = 0.87–0.89$ which is a satisfying solution to the question. The transfer function (4) is called *circular function*. The meaning is that the brightness from all pixels that are connected to a given pixel is being averaged. The number of these pixels is 8.

We can get better result by using the evolutional scheme. If we have images with 4, 16, 64 pixels resolution on our disposition, then we can build the function $B_{ij} = f(p)$. In this case, B_{ij} is the brightness of each cell, and p is the number of the pixels in the image. The description of such function for several types of cells of the image is shown on Fig. 6. They can be approximated by the following function:

$$B_{ij} = a(\lg p)^2 + b\lg p + c. \quad (5)$$

It is possible to perform more complex approximations, but they don't lead to a similar end result.

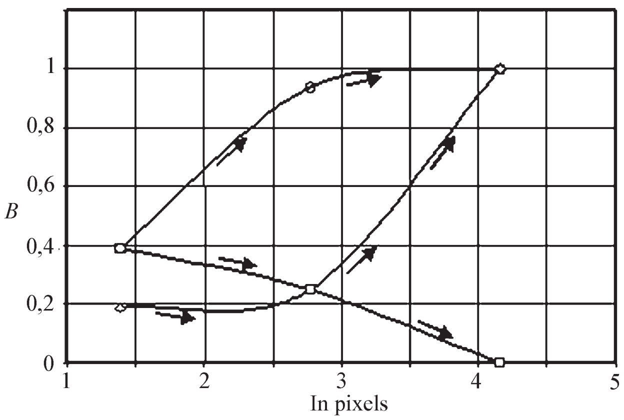

Fig.6

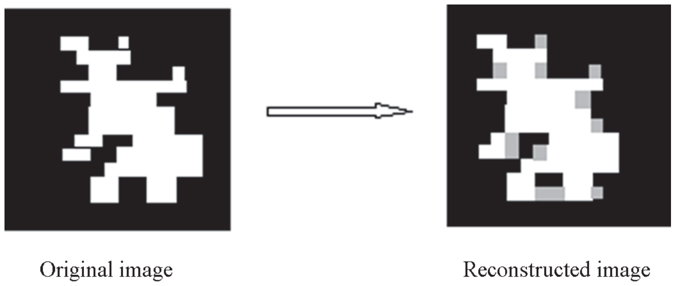

Fig.7

The reconstruction of the image of Fig. 5*a* from the image from Fig. 5*b* using equation (5) is represented in Fig. 7. The pixels that do not correspond to the original image are shown with gray raster (present or absent in the reconstructed image). As we see, they appear in the boundary parts of the white contour and the parts where the shape is too complicated.

4. CONCLUSIONS

The determination of the snow coverage of mountain chains is frequently demanded by the practice. If we do not have image with high resolution we can acquire it from image with lower resolution. There are different possible solutions:

1. One of them is to obtain image with four time greater resolution. For this aim, we use the introduced new *circular function*. The difference between the acquired new image and the original one can be about 10-15%.

2. If we have at least two images of one definite object with lower resolution, we can build the introduced new *evolutional function* for each cell of the image. It gives us a vision how the brightness is evaluating in each cell of the image with transformations from simpler to more complex image. In this case the acquired new image can be different from the original with 8-10%. This is accuracy is satisfying and it increases if we have more than two images.

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