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Enhancement of lineal elements in black and white images by optical pseudocolouring *

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In this paper a two-colour, two arm coherent-incoherent optical system for real time pseudocolouring is described. The incoherent arm enables to obtain a high quality one-colour image. In the coherent arm, the spatial frequency filtering process leading to the enhancement of the desired features (for instance, high spatial frequency components) of the input image is performed in another colour. Both images overlap in the output plane of the whole system giving one pseudocoloured image. Possible applications — pseudocolouring of the biological and metalographic photomicrographs as well as aerial and satellite photographs — are illustrated.

1. Pseudocolouring of the lineal elements

There are several typical methods of pseudocolouring. One of them is based on ascribing particular colours to different gray levels in the black and white input image (optical density pseudocolouring). The second method consists in the colour encoding of the Fourier components of the input image (spatial frequency pseudocolouring). It is possible also to combine both the mentioned above principles (hybrid pseudocolouring).

Different techniques used for obtaining the pseudocolour images (i.e., the techniques based on the image plane holography or rainbow holography, or on the spatial frequency filtering or on the scattering properties of the photographic emulsion, etc.) are described in details in many papers. We are not of the opinion that it is necessary or useful to refer every time to the whole long list of references. Therefore we will limit ourselves to quoting several recent papers [1–5] distinguished either by the more general approach to the pseudocolouring problem, or by beautiful colour photographs illustrating the described effects, when a more comlete list of references can be easily found.

However, the pseudocolouring problem seems to be not completely exhausted yet. Sometimes the mentioned above methods are not sufficient to obtain the particular features of the objects and scenes recorded in the black and white image. For instance, only the details of a given shape or specific microstructure might be of interest. As an example of such a problem the pseudocolouring of directional structures presented in paper [6] can be quoted.

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In this paper we would like to present a method for the pseudocolouring of the lineal elements independently of their directions. This method applied to the pseudocolouring of the aerial and satellite photographs as well as to the metallographic or biological photomicrographs enables to enhance by colour the line- and point-like elements, such as edges, boundaries of uniform regions, long and thin elements of structure, etc.

2. Experimental set-up

According to the suggestions contained in paper [6] and the proposal of an optical system for pseudocolouring given by Santamaria et al. in [7] we have chosen a set-up composed of two arms: a coherent one and the other incoherent. In the coherent light, it is possible to perform the modification of the input image by means of spatial frequency filtering. The incoherent illumination, in turn, enables to obtain the high quality image free from coherent noise. If in both arms of pseudocolouring system the light of different colours is used, then both images of the same object formed in the different arms of the set-up have different colours. A pseudocoloured image is then obtained as the result of overlapping of the two mentioned unicolour images.

The schematic diagram of optical set-up is presented in Fig. 1. As it was already pointed out, it is composed of two parallel arms. One of them is a typical

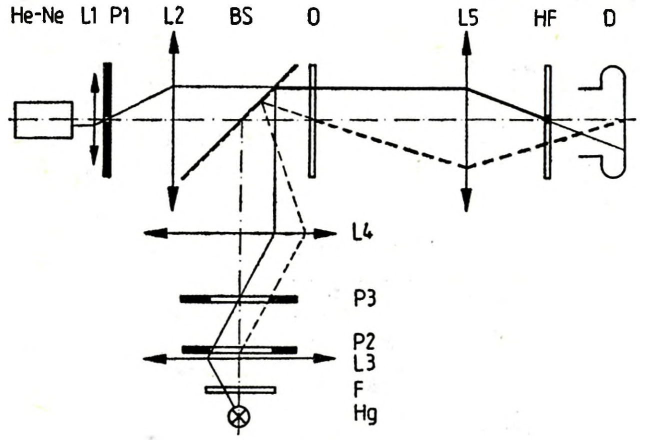
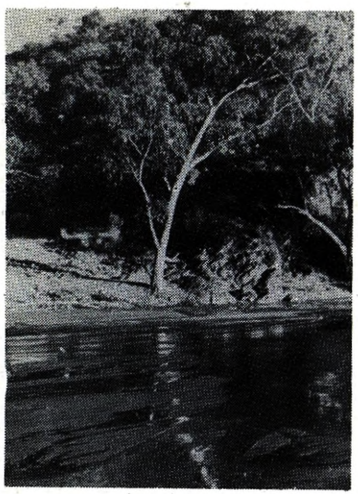


Fig. 1. Schematic diagram of optical set-up for pseudocolouring (explanation in text)

incoherent imaging system with the illuminator of the Köhler type giving incoherent but quasi-monochromatic light. It is built up of two lenses, L3 and L4, the field and aperture diaphragms P2 and P3 and the incoherent light source Hg (e.g., high pressure mercury lamp) with the colour filter F. The second arm of the optical set-up is a coherent optical system for spatial frequency filtering. Its illuminating part is composed of the cw laser He-Ne and a collimator (lenses L1 and L2, and a pinhole P1). The beam splitter BS joins both



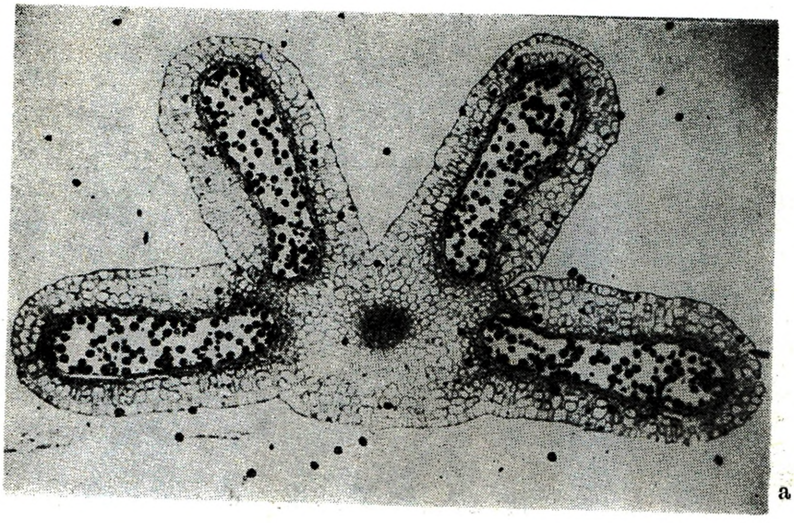
a

b

d

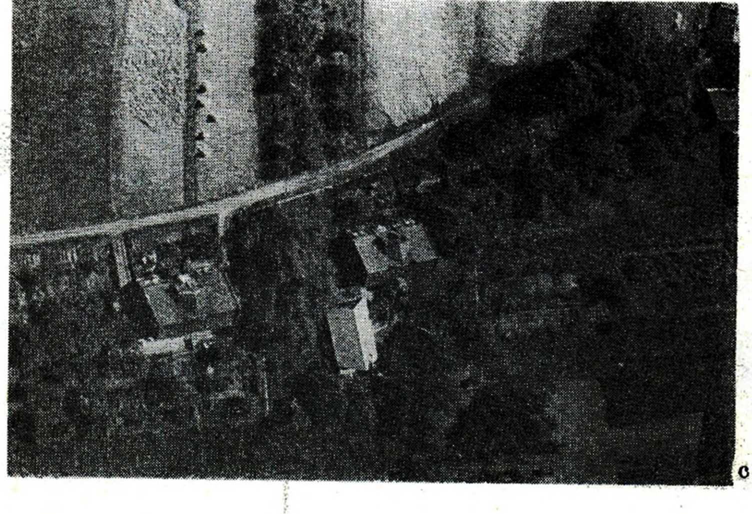
e

Fig. 2. Black and white test object (a). Pseudocoloured images of the test object differing in the colour balancing (b-e)

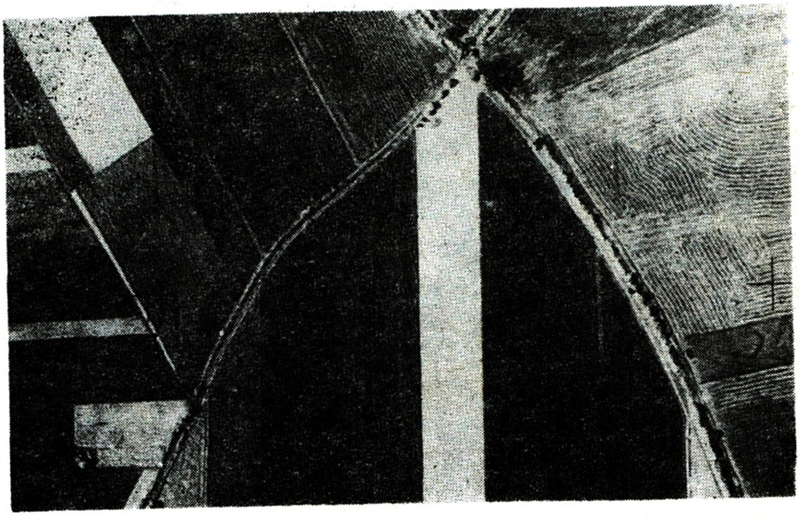


a

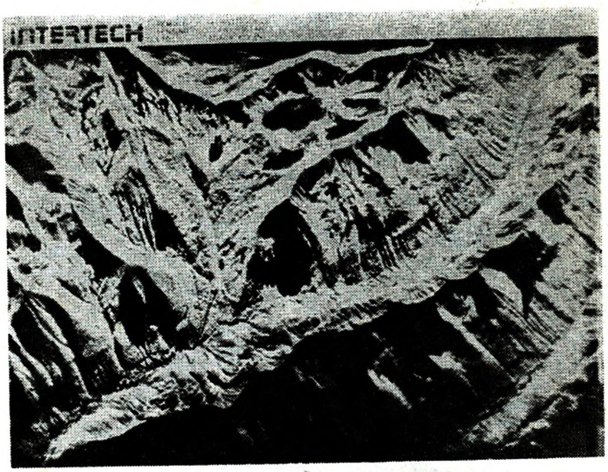
b



c



d



e

f

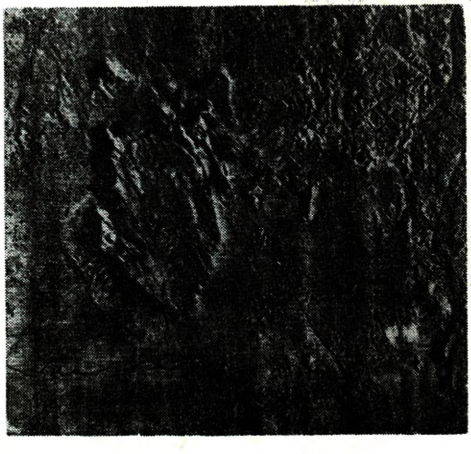
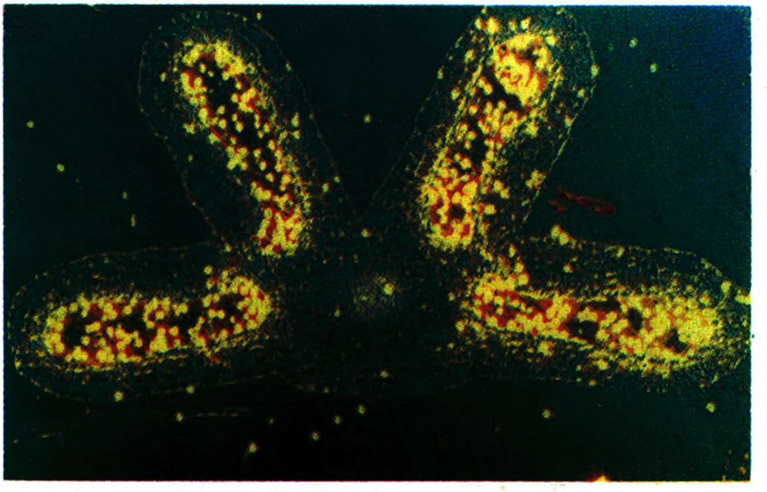
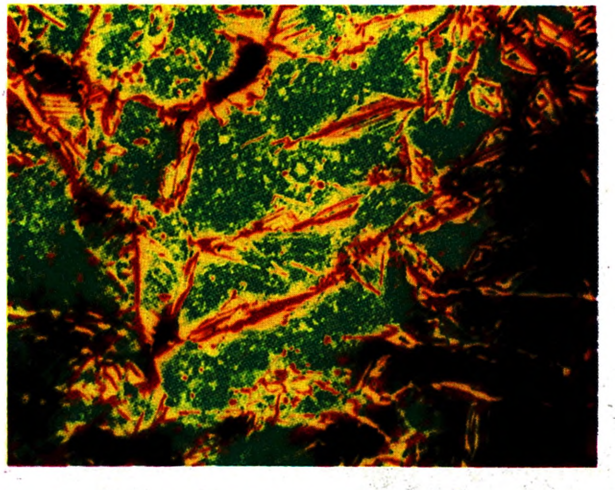


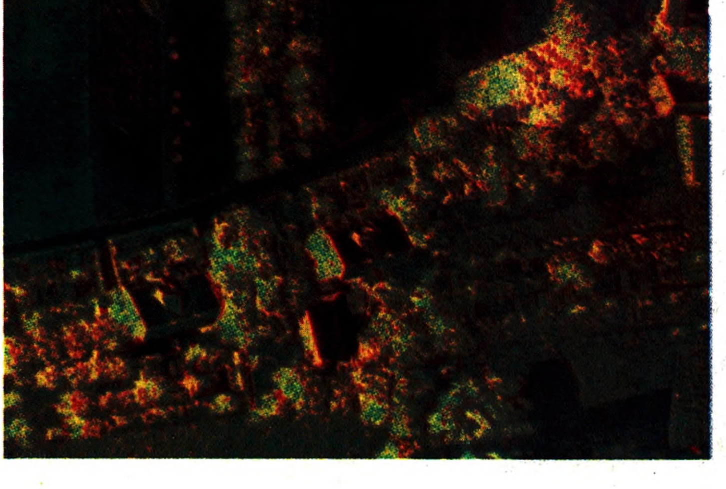
Fig. 3. Black and white objects to be pseudocoloured (a–f)



a



b



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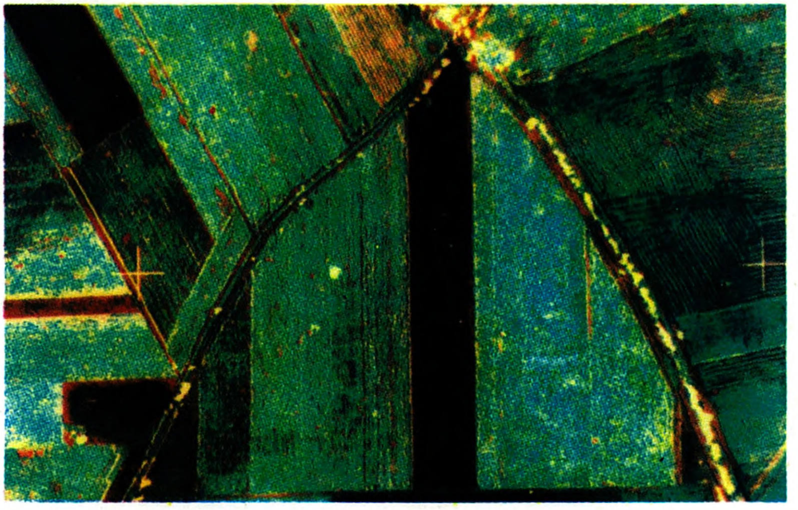

d

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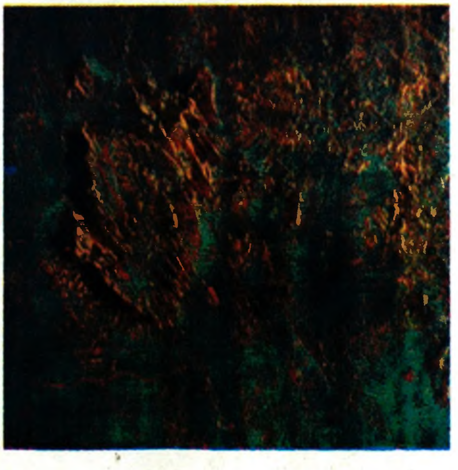

Fig. 4. Pseudocoloured images of the objects presented in Figs. 3 a-f

the arms together. The object, in the form of black and white transparency, is placed in the plane O. Lens $L5$ plays the role of the imaging and transforming lens as well. Spatial filter HF is located in the plane being the Fourier plane of the coherent arm and the exit pupil of the incoherent imaging arm. D denotes the plane of pseudocoloured image observation and recording.

If the average transmittance of the spatial filter HF is high (it is so, when the opaque regions of the filter cover only a small part of its overall area) then its influence on the incoherent imaging may be neglected. In the detection plane D an incoherent image of one (e.g., green) colour and high resolution is formed.

The other image observed in the same plane, but having another colour (e.g., red) is a processed image of the input object. Its character depends on the used spatial filter HF. If the typical high pass filter is applied the red image contains only high spatial frequency components of the object, i.e., lineal or point-like elements as well as the contours of the uniform extended regions. Therefore, in the resulting image the mentioned above details are visible in red or yellow, while the uniform areas are displayed in green.

3. Results

In this section the results of pseudocolouring performed with the help of the described method will be shown and attention will be paid to the possible applications.

Figure 2a presents the exemplary black and white halftone photograph to be pseudocoloured. The obtained pseudocoloured images are presented in Figs. 2b–e. Their colour scale differs as the ratio between red and green components is changed. It can be done by changing the diameter of diaphragm P3. Therefore for each object to be pseudocoloured it is possible to fit the optimum colour balancing considering the observer's convenience.

The examples of application are shown in the next figures. Figure 3a is a photomicrograph of a plant tissue. In its pseudocoloured image (Fig. 4a) it can be noticed that the cell's pellicles are displayed in yellow. The metallographic photomicrograph (the CoAl alloy) is presented in the Fig. 3b. Red lines in the pseudocoloured image (Fig. 4b) are the traces of dislocations. The examples of the aerial black and white photographs are shown in Figs. 3c and 3d, while its pseudocoloured images — in Figs. 4c and 4d, respectively. Figure 3e presents the radar image of the Earth surface and the Fig. 4e is its pseudocoloured version. The exemplary satellite photograph is shown in Fig. 3f and the results of its pseudocolouring in the Fig. 4f.

4. Conclusions

The optical system presented in this paper is composed of two arms: coherent and incoherent ones. Incoherent illumination enables to obtain the high quality image with no resolution loss which, unfortunately, occurs in typical coherent filtering systems because of speckling and spatial filter influence. The coherent illumination, in turn, gives a possibility to enhance some features of processed image by spatial frequency filtering.

Apart from the described high pass frequency filtering resulting in colour enhancement of the points, lines and edges in the black and white input image, other types of spatial filters can be used. By proper filtering it is possible to obtain a negative coherent image which leads to the optical density pseudocolouring. By application of spatial filters matched with the particular objects and details it is possible to distinguish them by different colour in the pseudocoloured image.

It is important that the colour balancing can be changed continuously, since then for each input image to be pseudocoloured an optimum colour scale can be found. It is possible also to enlarge the system by adding the third or the following arms with other spatial filters and operating in the other colour which would offer the extension of the colour scale of the pseudocoloured image.

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Заостренность линеарных элементов черно-белых изображений путем оптической псевдорасцветки

Представлена двухцветная, когерентно-некогерентная, двухветвистая оптическая система для псевдорасцветки за реальное время. Некогерентная ветвь позволяет получить одноцветное изображение высокого качества. Во второй, когерентной ветви производят процесс фильтрации пространственной частоты, ведущий к заостренности желательных черт входного изображения (напр. его составляющих с высокими пространственными частотами) для другого цвета. Оба изображения накладываются в выходной плоскости всей системы, в результате чего получается псевдорасцвеченное изображение. Иллюстрировано возможное применение как псевдорасцветки биологических и металлографических микрофотографий, так и аэросъемок, а также спутниковых съемок.