Optic-electronic processing of images

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Abstract: Problem of technical objects low contrast image areas analysis is actual. Even now the black and white photo materials are used along with colour images. Particularly it can be attributed to X-ray control. The majority of industrially produced photo layers are colourless. As a rule, images are analyzed visually. In particular such method is used in medical X-ray control. Up to a present moment there are no reliable algorithms capable of separating pathological and non-affected areas. If an image is sufficiently clear and contrast then it is analyzed using the primary photo-image. If the image has low contrast then a researcher, firstly, converts it into a pseudo-colour or three-dimensional and then analyses it. Such procedure is determined by complex dependence of many factors, but the most important are the following three: psycho-physiological complexity to distinguish the boundaries of the image, difficulty to create an algorithm capable of recognizing the norm-pathology boundary without help of a human, and inability of an average human eye to discern more than 10 - 12 gradations on black and white image. Existence of the mentioned factors led to various approaches to obtaining higher quality of images - the image pseudo-colour coding method, and the method of 3-D conversion. In the present paper the combination of the developed and patented by the author method for optical images analysis and well known method of computer image analysis using Femtoscan software (designed for electronic microscope images analysis) is considered.

1. Introduction

Development of technologies for improvement of quality of half-tone black-and-white and colour images is important in areas of X-ray techniques, interferometry, geocology. That is required for obtaining more reliable information contained in the images but not been ready for direct analysis. The purposes of the present paper are description and demonstration of possibilities of images quality improvement by the optical analysis in diffuse light for the cases of weld, hand and burning gas flare. The initial X-ray image of the weld is shown on fig.1, fig.2 represents the initial X-ray image of the hand and fig.3 shows the initial X-ray image of the burning gas flare. Let us briefly describe fundamentals of the theory of colour perception. Young-Helmholtz theory of colour vision assumes that the whole spectrum, from violet to red, is formed in a human brain. However, the human eye retina has only three types of cones each having maximal sensitivity for one of the three colours: violet, green and yellow-green. The last of the mentioned retina cones are also sensitive to red colour but the sensitivity is lower by an order of magnitude. The three above mentioned colours correspond to the wave lengths of 430, 543 and 564 nm. It should be mentioned that in the additive theory of colour it is customary to mix slightly different colours: blue, green and red, which correspond to the wave lengths of 440, 520 and 700 nm according to standards of International Commission for Lighting.
Figure 1. Black-and-white X-ray image of a weld

Figure 2. Half-tone X-ray image of a hand
There exist at least several approaches for solving this problem. One of them, the method of clusterization, is described in details in [1, 2]. Several methods are known for the clusterization, the method of k-averages should be pointed out. The method is efficient but has one significant drawback - it is necessary to know a priori approximate number of the clusters. Segmentation of the image allows to decrease the amount of information required for storing the image and, hence, to make subsequent analysis of the image easier. This advantage of segmentation is at the same time its drawback - if an image is segmented then some information is irreversibly lost and can not be restored. Another possible solution can be using recurrent neural networks [3]. In addition, there exists the method of pseudo-colour coding based on the image inversion [4]. The method was initially developed for improving quality of images obtained on the classic photo layers containing haloid silver. The essence of the method is that micro-crystals of haloid silver absorb and scatter incident light. The image in scattered light is weaker than the image in through-passing light. But these two images are complementary, i.e. their dark and white areas are interchanged. Then these two complementary images were coloured by complementary colours, using red and blue light filters, and were superimposed with each other. As result the pseudo-colour picture was obtained. In that case it was not necessary to know a priori the number of clusters. And this is an advantage of the method. The main drawback of the method is impossibility of real-time operation. In the review paper [5] several modern approaches to processing of various images are considered. There are considered information-measuring complexes of three levels: low, middle and high. Noise reduction and contrast enhancement are related to the operations of the low level. Segmenting and compression belong, by the authors’ opinion, to operations of the middle level. And operations of the high level involve understanding of the processed objects, in other words primitive modeling of a human's brain work. Some operations of the low and middle level are required for improving those image parameters that are important in comprehension of the images by a human. The operations of the high level are automatic image processing operations without a human participation. The example of such operation is a quality control of apples during automatic sorting. As the image processing the authors consider the following operations. The first operation is modifying pixels for noise reduction. The second operation is improving an image quality in general, for instance increase or decrease of intensity over the whole image area. Thus, too dark or too bright images are brought to an average brightness. The third operation is combining several images, usually addition or subtraction. The subtraction of several consecutive images allows revealing the process dynamics. The fourth operation is binarization of images. It separates objects having brightness exceeding specified threshold. In the paper [6] the authors
propose using statistical processing of optical digital images. The authors believe that such processing improves quality of investigations. The computer program has been developed for experiments involving statistical analysis. That seems to be important in science of crime detection for comparison of stamps and signatures images colorimetric parameters. The program is also developed for profile (micro-relief) measurement of a barrel rifling traces on a bullet. Efficiency of the programs has been experimentally demonstrated. The required accuracy was proved. The authors of the mentioned paper described the program for comparing some parameters of a colour background in original and fake images. That program compares parameters of coloring matter in the images. This leads to improvement of an analysis objectivity and decrease of the analysis duration. Reliability of the analysis was proved by experimental research and by other methods. Early detection of lungs pathology \[7, 8\] using analysis of X-ray images allows carrying out timely and efficient treatment. At present analysis of X-ray images in medical practice in Russian Federation is performed visually. The authors of the referenced paper think that digital processing of images can increase reliability of diagnostics. That, in its turn, would lead to timely diagnostics of a disease and efficient treatment. In such case lung anomalies on the X-ray image can be revealed before they could have led to serious clinical symptoms. Such analysis also allows monitoring a disease dynamics during the disease development and treatment. The first aim of the paper was to provide basic knowledge on a fractal analysis for practicing doctors not educated in area of informational instrumentation. The second aim is to prove possibilities of the fractal analysis method for processing medical research data and efficiency of their use in diagnostics.

2. Research
The purpose of the paper is to demonstrate the possibility of optical inversion and then pseudo-colour coding of black-and-white image taken from the screen of LCD monitor. In the beginning let us briefly describe possibilities and, found by the authors, drawbacks of well known software Femtoscan. This software is physically based on using YUV colour space. This space is widely used in TV broadcasting and came to computers together with MPEG format. The essence is that the human eye is much more sensitive to chromaticity of an image and less sensitive to image brightness. The drawback of Femtoscan is the decrease of its resolution capacity over the image field with increase of chromatic resolution. This leads to lost of small elements of the image. If the researcher a priori does not need to store small elements then the mentioned drawback can be neglected. In YUV colour space Y represents brightness. Two other components U, V represent chromaticity. Thus, Femtoscan software uses only two components, not three, to create pseudo-colour image. The chromatic possibilities of an eye in this case are used only partly.

In classic photo layers the possibility of image inversion is directly related to approximate correspondence between haloid silver grain sizes and wave length of visible light. In this case also only two complementary colours are mixed, blue and red, resulting in pseudo-colour image. But when working with halogenide layers no image losses take place. Obviously, the drawback of the halogenide photo layers is the long duration of analysis. This method is applicable only for the unique images, when duration is not of principal importance. The author of the present paper proposed using the effect of the image inversion on the screen of LCD monitor. It is clear that size of an element on the monitor screen is not comparable with the wave length of visible light. The patented effect of scattering should not be observed. Nevertheless, the effect of inversion of a half-tone image and subsequent colouring it in pseudo-colours sometimes, rarely, but was observed on the LCD screen of a monitor. Understanding came later that the effect can be observed when two sizes approximately are close - the size of the element of the LCD screen and the size of the elements of the image. The size of the screen element can not be changed while the image element size can be varied by image scaling (zoom). Thus, the proposed method seems to have drawback - the image should have only specified, discrete scaling factors. Parameters of the optical glasses "C3C-22" and "KC-11" are well known to Russian researchers but can be unknown for researchers from abroad. Therefore we represent their characteristics in details. The glass is produced according to the Russian Federation standard "GOST 9411-91 "Steklo optitcheskoe tsvetnoe." Technical specifications, with correction. Abbreviation "C3C" stands for blue-green glass, digits 22-specific notation. Parameters of the glass are presented for the wave lengths 400, 460 and 600
nanometers. The transmission wavelength range of the standard two millimeters specimen is from 380 to 570 nanometers. The authors used for experiments the analogous produced in Russia blue glasses of types "СЗС-16", "СЗС-17", "СЗС-20" and "СЗС-21". The first set of experiments involved theoretical and experimental choice of the one of the above mentioned glasses type and the one red colour glass. There are following types of produced in Russia red glasses "КС-10", "КС-11", "КС-13", "КС-14" and "КС-15". The abbreviation "КС" stands for red glass, digits show an ordinal number. Calculations show that the maximal effect is achieved for the combination of "СЗС-22" and "КС-11". The second set of experiments involved the choice of the best combination of the glasses thicknesses. Calculations as well as experiments revealed that the blue glass should be thicker than the red glass by the factor of 1.5. It is for such ratio the mixed blue and red images give green image with the wavelength of about 570 nanometers. Note that an average human eye has the maximal sensitivity at this wave length.

3. Results and discussion

Let us describe the experiment. The initial half-tone and black-and-white images, shown on figs. 1-3, were observed in the direction not normal to the screen but under the specified angles of opposite signs. The absolute values of the angles were within 15-30 degrees. Then the scaling of the image was gradually being change until the two images become complementary. Then the both images were registered by a digital photo camera through optical light filters made of the optical glasses "СЗС-22" and "КС-11". The next operation was superimposition of the images and stretching in the vertical direction up to the scaling of the initial image. Then, after having obtained a principally positive result, the scheme of the experiment was modernized. The digital photo camera was positioned normally to the monitor and the view angle was being changed by two plane-parallel mirrors. The results of the images inversion by the proposed optic-electronic method are represented on figs. 4-6. We used digital photo-camera Canon Power Shot SX620HS having the following main characteristics: matrix of 21.1 Megapixels, screen of 3 inches, capable of macro regime of taking pictures. The angles were taken in the range 15-30 degrees with 1 degree step. The ACER ExtensaEX2519-C33F monitor was used in experiments. The reason to use this relatively cheap model was the fact that the monitors of more expensive models do not have the effect of appearing complementary image when the observation angle is in the range from minus 30 to plus 30 degrees in a vertical plane. Figure 4 represents initial black-and-white half-tone images of a weld taken with different expositions. Remember that the sensitivity of an average human eye to intensity changes is around 10%, thus it is possible for each image to discern not more than 10 brightness gradations. In order to provide more half-tones it is required to take pictures with different expositions and then compare the whole series of the pictures, all 7 images. If we apply pseudo-colour images coding then only one primary black-and-white image is enough, for instance the middle image "b" from the series of figure 4. Note that in industrial X-ray imaging only black-and-white photo-layers are used now. Thus, the proposed method using analysis of half-tone X-ray images allows saving expensive picture material.

Concerning medical half-tone X-ray images, one of which is on the figure 2, the method allows decreasing the exposition dose obtained by a patient. In order to reveal image details having different density it is necessary to take several images with different exposition. Application of the proposed method allows taking one primary image the subsequent processing of which, as seen on the figure 4, can reveal many image details not visible on the primary image 2.

In the third case of the analysis of half-tone gas flare image, figure 3, the pseudo-colour image coding allows estimating, at least approximately, the gas flare temperature, and hence helps in making decision on the most efficient way for extinguishing the fire.
Figure 4. Pseudo-colour model for X-ray image of the weld

Figure 5. Pseudo-colour X-ray image of the hand
4. Conclusion
The possibilities of the optic-electronic pseudo-colour coding of images in real-time are briefly considered. The proposed method in no way diminishes the importance of the other methods but can add and extend their functionality. The colour segmentation of black-and-white images is preferable in real-time operation using analysis of the image on a LCD monitor screen. In this case the pseudo-colour image is represented using RGB model and the major part of the image corresponds to the green range of spectrum to which the human eye is the most sensitive. Using the method of images pseudo-color coloring it is possible to determine a location of a human organ having some pathology [9].

References

[1] Nemirovskiy V B and Stoyanov A K 2017 Computer Optics 41 pp 59–66
[2] Nemirovskiy V B, Stoyanov A K and Goremykina D S 2016 Computer Optics 40 pp 740-745
[3] Nemirovskiy VB Stoyanov AK 2012 Bulletin of the Tomsk Polytechnik University pp 205–210
[4] Suvilova K A Polezhaeva A I Noskov M F Tatarnikov V I Rubanovich M G Razinkin V P 2017 International Conference of Young Specialists on Micro/Nanotechnologies and Electron Devices EDM-2017 pp 368–370
[5] Kolobrodov V Pozdniakov D Sokurenko V Tiagur V 2017 Eastern-European Journal of Enterprise Technologies pp 46-52
[6] Kozlov V I Vasilchuk A S 2015 Devices and Methods of Measurements pp 220- 229
[7] Noskov M F 2018 14th International Scientific-Technical Conference APEIE – 44894 pp 140-142
[8] Shi Z M 2011 Engineering Fracture Mechanics 78 pp 503-513
[9] Lisitsyna Lilia I, Blokhin Alexander A, Starovoytova Tatiana M, Navrotsky Leonid G, Natalia S Chirkova and Alexander M Fateev 2017 Dependence of Brightness of a Glow of Points of Compliance on Heart Rate EDM-2017 (Novosibirsk: NSTU) pp 613–615