Computer simulation of the multiplicative method for the formation of digital spectrozonal images

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Abstract. The article discusses the features of the formation of digital spectrozonal images corresponding to narrow registration zones. It analyses the processes of signal transformations with the multiplicative method of forming digital spectrozonal images. The results of computer modeling are discussed with the aim of qualitative and quantitative comparison of images obtained with differential and multiplicative digital spectrozonal imaging. An example of images of test objects obtained by the differential and multiplicative method from the original digital spectrozonal images is given.

1. Introduction

Digital spectrozonal imaging involves the conversion of digital copies of the original spectrozonal images in order to generate signals corresponding to the new areas of registration of the radiation spectrum. Differential methods are of practical interest among digital methods [1–7].

So, in particular, according to the method described in [5, 6], the formation of digital spectrozonal television signals is carried out as follows. The initial matrices \(U_1, U_2, \ldots, U_n\) of brightness samples of spectrozonal images are obtained in overlapping wavelength intervals \(\lambda_1, \lambda_2, \ldots, \lambda_n\), where \(\lambda_1 < \lambda_2 < \ldots < \lambda_n\). Then the differences are calculated \(U_{\text{out1}} = U_1 - U_2, U_{\text{out2}} = U_2 - U_3, \ldots, U_{\text{outn-1}} = U_{n-1} - U_n\), corresponding to narrow registration areas \(\lambda_1, \lambda_2, \lambda_3, \ldots, \lambda_{n-1}\). The resulting matrix of samples of brightness of the spectrozonal images is formed in accordance with the expressions \(U'_{\text{out1}} = (U_{\text{out1}} + U_{\text{max}}) / 2, U'_{\text{out2}} = (U_{\text{out2}} + U_{\text{max}}) / 2, \ldots, U'_{\text{outn-1}} = (U_{\text{outn-1}} + U_{\text{max}}) / 2\), where \(U_{\text{max}}\) is the highest possible digital code value.

However, the resulting differential images, as a rule, have a low contrast, since the differences of the corresponding brightness samples \(U_{\text{out1}} = U_1 - U_2, U_{\text{out2}} = U_2 - U_3, \ldots, U_{\text{outn-1}} = U_{n-1} - U_n\) are very small compared to the dynamic range of the possible signal changes.

The purpose of this article is to familiarize with the results of computer simulation of the method of multiplicative spectrozonal imaging, which consists in multiplying the original spectrozonal signals received in overlapping recording zones.

2. Results and discussion

The method of multiplicative spectrozonal imaging under decision consists in generating matrices of brightness reports for spectrozonal images corresponding to narrow recording zones \(\lambda_1, \lambda_2, \lambda_3, \ldots, \lambda_{n-1}\), by the following transformations. The calculations are performed according to the formulas...
\[ U_1^a = [U_2^a(U_{\text{max}} - U_1)], \quad U_2^a = [U_3^a(U_{\text{max}} - U_2)], \quad \ldots \quad U_n^a = [U_{n-1}^a(U_{\text{max}} - U_{n-1})]. \]

The calculation is also possible by the following formulas
\[ U_1^a = [U_2^a(U_{\text{max}} - U_1)], \quad U_2^a = [U_3^a(U_{\text{max}} - U_2)], \quad \ldots \quad U_n^a = [U_{n-1}^a(U_{\text{max}} - U_n)]. \]

Then the maximum values are determined \( U_1^a_{\text{max}}, U_2^a_{\text{max}}, \ldots U_n^a_{\text{max}} \) of the corresponding matrices \( U_1^a, U_2^a, \ldots U_n^a \).

The resulting matrix of samples of brightness of the spectrozonal images is formed in accordance with the expressions:
\[ U_{\text{out}1}^a = [U_1^a(U_{\text{max}} / U_1^a_{\text{max}})], \quad U_{\text{out}2}^a = [U_2^a(U_{\text{max}} / U_2^a_{\text{max}})], \quad \ldots \quad U_{\text{out}n}^a = [U_n^a(U_{\text{max}} / U_n^a_{\text{max}})]. \]

**Figure 1.** Spectrozonal images \( U_1, U_2, U_3, U_4 \), obtained using standard yellow light filter (YLF) and red light filter (RLF).

When computer modeling the method of multiplicative spectrozonal imaging, we used matrixes of digital reports of spectrozonal images \( U_1, U_2, U_3, U_4 \) shown in figure 1. Image data were obtained using standard filters YLF4, YLF18, RLF11 and RLF19 for extended spectral ranges from \( \lambda_1 = 400 \) nm, \( \lambda_2 = 500 \) nm, \( \lambda_3 = 600 \) nm, and \( \lambda_4 = 700 \) nm. The spectral characteristics of the standard filters for extended spectral ranges are given in figure 2.

**Figure 2.** Spectral characteristics of standard light filters YLF4, YLF18, RLF11, RLF19.
In computer simulation, transformations of the original matrices $U_1, U_2, U_3, U_4$ were carried out in accordance with the methods described above. The multiplicative method involves the inversion of one of the multiplicable matrices. The results presented in this article were obtained by inverting the matrix corresponding to a wider spectral range of two factors. The $U_{\text{max}}$ value during the simulation corresponded to the maximum of the dynamic range of the signal change and corresponded to 255 for 8-bit encoding.

Computer simulation was carried out in MATLAB. The resulting images by the differential and multiplicative methods were visually compared with each other, and a quantitative comparison was made of the corresponding maximum and minimum values of digital brightness samples.

Figure 3 shows examples of the resulting images obtained by the differential method (figure 3a) and the multiplicative method (figure 3b) with the corresponding processing of a pair of source matrices $U_2$ and $U_3$. The image obtained by the differential method (figure 3a) has low contrast. The contrast of the image obtained by the multiplicative method (figure 3b) is significantly higher.

![Figure 3](image3.png)

**Figure 3.** Spectrozonal images obtained by differential – a) and multiplicative – b) method.

A quantitative comparison of the differences between the maximum and minimum values of digital codes obtained by the differential method and the multiplicative method when processing the images shown in figure 2 is shown in figure 4. As we can see from the comparative diagrams shown in figure 4, the multiplicative method with respect to the differential one provides an increase in the contrast of images not less than by 1.5 times.

![Figure 4](image4.png)

**Figure 4.** Quantitative comparison of the maximum and minimum values of brightness samples in spectrozonal images obtained by the differential – a) and multiplicative – b) method.
3. Conclusion
Digital methods for spectrozonal imaging allow minimizing hardware costs for building optoelectronic systems (OES), expanding their functionality, which is of great practical interest.

Computer simulation shows the advantage of the multiplicative method of digital spectrozonal imaging in relation to the differential method. A quantitative assessment of the increase in image contrast is not less than by 1.5 times.

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