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Influence of Color Noise on Processing of Optical Signals by Swarm Intellect Algorithm

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Abstract. An approach based on stochastic particle swarm optimization was applied for the mathematical processing of spectral profiles with noise. To test the algorithm's stability with respect to noise, we used the noises with different values of the Hurst index which characterizes noise component from the point of view of prevalence of low-frequency or high-frequency component in it. The Hurst index varied from 0.1 to 0.9. An influence of color noise with level from 1 to 10% on processing of optical signals by particle swarm optimization algorithm was analyzed. This method is shown to be stable with respect to noise with the level of 10% if it's the Hurst index does not exceed the value of 0.5.

Keywords: spectral contour, particle swarm optimization, Hurst index, color noise.

In spectroscopic experiments the stability of algorithms of mathematical processing of optical signals with respect to noises of different nature is of practical interest in point of view of the correctness of the obtained results and interpretation of ones. An existence of the noise caused by both the nature of the studied object and the recording device does not allow to restore an initial complex spectral contour when being divided into components and to determine the intensity, the half-width, the position of maximum and the quantity of spectral components correctly in the case of small signal/noise relation.

Earlier we suggested the evolutionary particle swarm optimization algorithm in the problem of decomposing of complex spectral contours [1]. This method simulates a many-agents system in which agent-particles move toward optimal solutions by exchanging information with their neighbors.

In this work an influence of color noise on the processing of optical signals by the particle swarm optimization method is considered. As the model noise we used a set of fractal noises ξ_f [2]: $\xi_f = D^{-(H-1/2)}\,\xi_g$, where ξg is a noncorrelated Gaussian random process, $D^{-\nu}$ is a fractional operator of order ν, and H is the Hurst index which characterizes noise component from the point of view of the prevalence of low-frequency or high-frequency component in it. The value $H > 0.5$ for noises means that the given signal is of low-frequency (color) character. The Hurst index with the value $H = 0.5$ corresponds to the white (Gaussian) noise. As was shown in [3], the prevalence of the contribution from low-frequency components was revealed in the experimental noise as compared to high-frequency ones. Therefore, it was interesting to analyze the low-frequency noise with respect to its effect on the results of the spectral profile reconstruction by the particle swarm optimization method.

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To analyze noise stability of the algorithm when the component's parameters are calculated we used a model spectrum with two components in Gaussian form. Fractal noise with various values of the Hurst index H from 0.1 to 0.9 was imposed. Besides, we varied the noise level η from 1 to 10% by step of 1%. In Fig. 1 the model noisy contour ($H = 0.1$, $\eta = 10\%$) is represented.

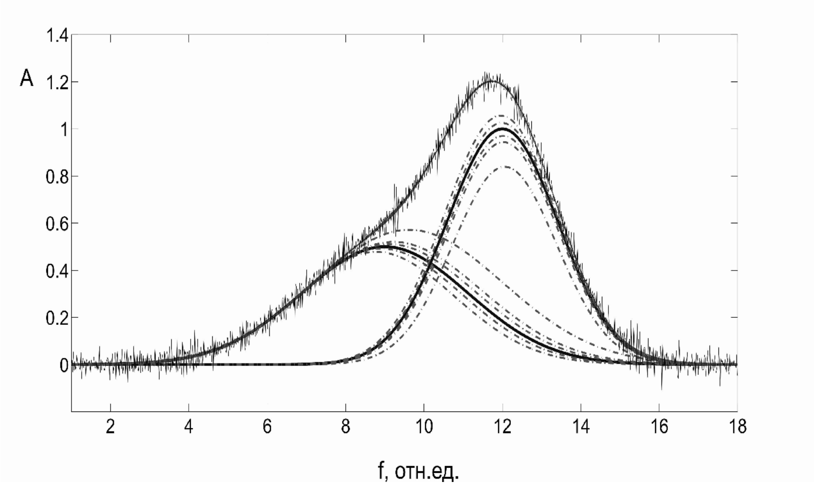

Figure. 1. A model of noisy contour (the Hurst index $H = 0.1$, noise level $\eta = 10\%$) and possible options of component restoration

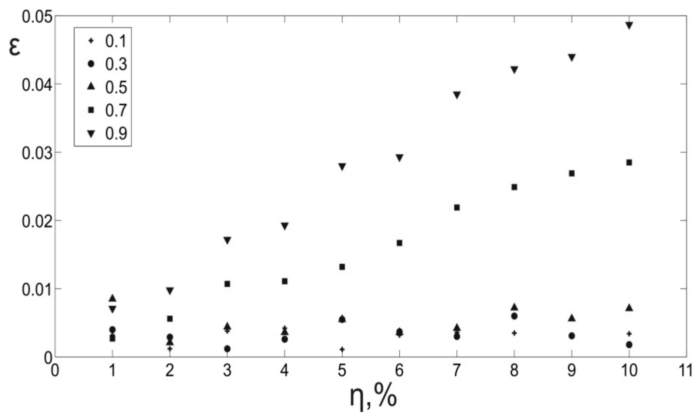

Figure 2. Dependence of the total contour (on the area) recovery error on a noise level for various values of the Hurst index: $H = 0.1$; 0.3; 0.5; 0.7; 0.9.

Figure 2 shows the dependences of the restoration error of a total contour (on the area) on the noise level for various values of the Hurst index: 0.1; 0.3; 0.5; 0.7; 0.9.

The obtained results show that the method based on the particle swarm optimization algorithm is stable with respect to the noise with the level up to value of 10% if its Hurst index does not exceed value of 0.5. With the Hurst index increasing, the restoration error increases, that is explained by the prevalence a low-frequency noise component and the corresponding distortion of spectral profile.

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