Correction of the contrast of a remote image based on small disturbances of the selected objects

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Abstract: Perturbations of the contrast of regular components in the distance image are determined and corrected by comparing the selected objects in the image with reference - reference landmarks. The corresponding disturbances for the distributed and stochastic components in the image are not always explicitly identified, since they are also caused by their distribution functions.

The paper proposes to implement the correction of the contrast of a remote image in the range of linearity of its change relative to the formed pairs "reference object - reference point" or a priori known indices of the contrast disturbance of the selected objects. In this case, the assumption about the homogeneity and isotropy of the image formation algorithm over the entire synthesized frame is used.

Keywords: spatial frequency spectrum, reference landmarks, distance image

Introduction

Comparison of regular patterns in images and detection of mutual perturbations can be realized by simple pixel-by-pixel subtraction of images from each other (with preliminary necessary transformations of mutual residuals of scale, translation, and rotations), and to solve the problem of identifying perturbations of stochastic components, it may be necessary to additionally apply theorems of statistical analysis of the presented pictures (with modeling of perturbed distribution functions of random variables).

Disturbances of the regular components in the image can be determined even visually, especially by comparing with selected reference or reference objects - reference landmarks. Disturbances, for example, of stochastic components in the image, especially in terms of their distribution functions, are not always represented in the image in an explicit form.

The paper proposes, based on the indices of the perturbation of the contrast of the selected objects relative to the reference objects (or a priori known), to implement the contrast correction on

the existing background based on the assumption of the uniformity and isotropy of the image formation algorithm.

Purpose of the study

Implement algorithms for correcting the contrast of objects in the image under consideration based on a computable representation of the Bates and McDonnell model.

Materials and methods

Perturbations of the parameters that determine the transfer characteristics of the analog-digital paths of optical and quasi-optical radio engineering systems (including the signal transmission medium) oriented to work with spatial objects often lead to an increase in the bands (and sections, in the general case) of the intersection of spectral portraits (SP) of the observed objects and noise components in the paths of transit of remote information. This fact, in terms of the impact on the result of the systems operation, is assessed as a deterioration in the resolution, quality factor, clarity, etc.

For classes of radio engineering systems with remote sensing modules, represented in accordance with information processing algorithms by the Bates and McDonnell model [1,2,3], it is possible to define a list of algorithms for the so-called secondary information processing: noise reduction, spectral and correlation analysis, correction and restoration of resolution the ability of the probing paths and the informative properties of the synthesized images (including based on the use of a priori information about the observed objects). The aforementioned perturbations of the parameters of radio engineering systems can be considered in the main part of the Bates and McDonnell model representing them as perturbations of the execution of binary bilinear operations of a computable representation of the model (provided that it is represented in the algebraization of the problem by bilinear forms (of the form (ax+b) (cx+d)), for example, where the x-vector of "useful" data, and the remaining elements of the bilinear form are the numerical values of the parameters characterizing the technique of receiving information).

These operations as part of the algorithms of the model under consideration are objectively based on the performance of the multiplication operation, the use of which makes it difficult to implement the so-called adiabatic representation of the components of the system (a system with the absence of mutual influence of its elements).

Regular disturbances in the equipment and algorithms of its operation, when they do not exceed certain threshold values [4, 5], often make it possible to notice that the regular components (images of objects) in the synthesized images are disturbed in such a way that they can be represented by regular functions describing the results of observing the behavior stochastic components (and their distribution functions). In addition, if the disturbances of the regular components in the image can be determined even visually, especially on reference or reference

objects - reference landmarks, then disturbances of the stochastic components, especially in terms of distribution functions, cannot always even be described explicitly.

In this paper, spectral portraits of "disturbed" images are presented and considered, described by the following approximate relationship:

$$F_S^{Vi}(\omega) \approx F_S(\omega)(1 + \beta\omega^\beta), \tag{1}$$

where $\beta = \frac{\|V_i\|}{\omega_c}$, $F_S^{Vi}(\omega)$ – the original Fourier representation of the image S for a given perturbation matrix V_i, ω – spatial presentation frequencies, ω_c – weighted average spatial frequency in the spectral portrait of the original image. Relation (1) follows from the additive form of representation of the perturbed quantities: the perturbed parameter receives the perturbing effect in an additive form. At the same time, this approach involves the use of so-called small perturbations, which means the fulfillment of the requirement $\beta\omega^\beta \ll 1$, and with the provision of "broadening" the bands of the spectra of perturbed quantities by hardly one or two harmonics while maintaining the period of their location on the frequency axes. In such formulations of the problem, the band of the investigated spectrum of the perturbed value is often forcibly expanded into the high-frequency region by the assumed value, then for the frequencies placed with the initial period, their amplitudes are approximated under the continuation of the envelope of the rest of the spectrum. The appearance of "parasitic" high frequencies on the spectrum disturbance curve is suppressed by notch filtering.

Results

Fig. 1 and fig. 2 show the initial and difference images, which were obtained by processing the original image using a disturbing matrix with a small norm (0.05) and a matrix with a norm with a value of 0.3.
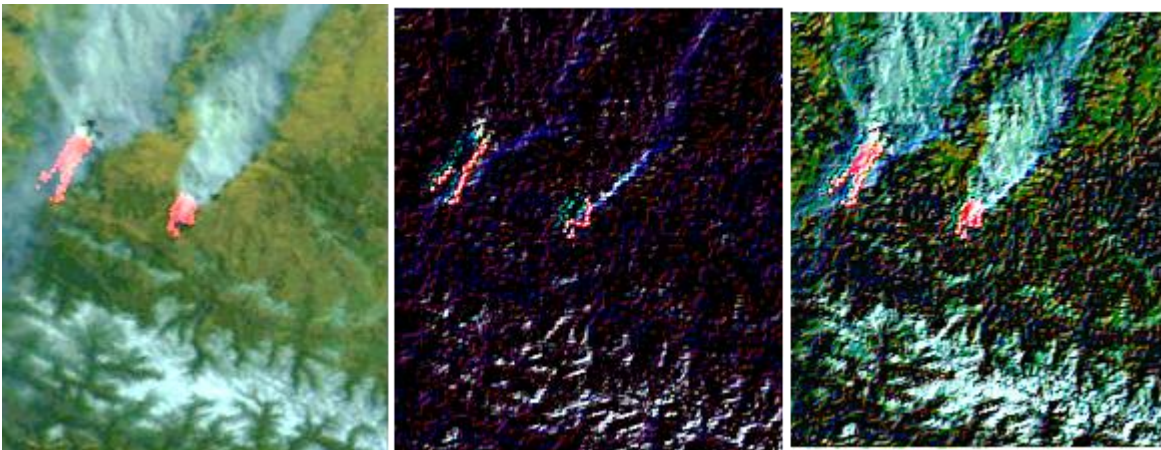

Fig. 1. Original image (left), difference image with perturbation matrix norm 0.05 (center), difference image with perturbation matrix norm 0.3 (right).
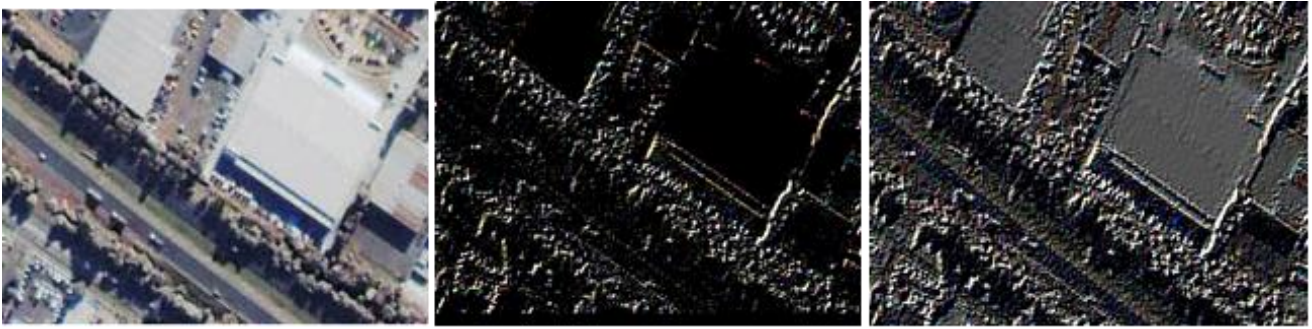
Fig. 2. Original image (left), difference image with perturbation matrix norm 0.05 (center), difference image with perturbation matrix norm 0.3 (right)

Fig. 1 (left) shows a space image containing mainly fractal images - fire centers in the taiga, framed by pseudo-regular boundaries. Fig. 2 (left) shows an image of a fragment of a city line containing approximately equivalent in amplitude low, medium and high SP modes. To the right are the difference images: "disturbed" minus the original one.

The difference spectral portrait (fig. 3) shows a low presence of changes in the low frequency region and a nonlinear increase in this change towards the periphery of the frequency axis, i.e. the fact of a steeper fall to zero of the spectral portrait of the verified image (in the region of the cutoff frequency) was recorded, which explains the improved signal-to-noise ratio determined by setting the cutoff frequency itself. In the original image, the corresponding measurement of the averaged signal-to-noise ratio gives a value of 75.6, which, with an error of about 6%, corresponds to the criterion of its increase by a factor of $\sqrt{2}$.

In fig. 3, the upper right image was obtained by transforming from the left one according to formula (1) with minimization of the perturbation matrix of the original image until an energy prevalence of the pixels of the right image over the left one by 2% -3% was obtained, observing the requirement $\beta\omega^{\beta} \ll 1$ when assigning its maximum spatial frequency for image values.

At the same time, the upper right quadrant of Figure 3 does not yet contain obvious nonlinear (inherent in images with power amplification) image contrast distortions. With a further increase in the energy prevalence of the right image, the linearity of the transformation began to break.
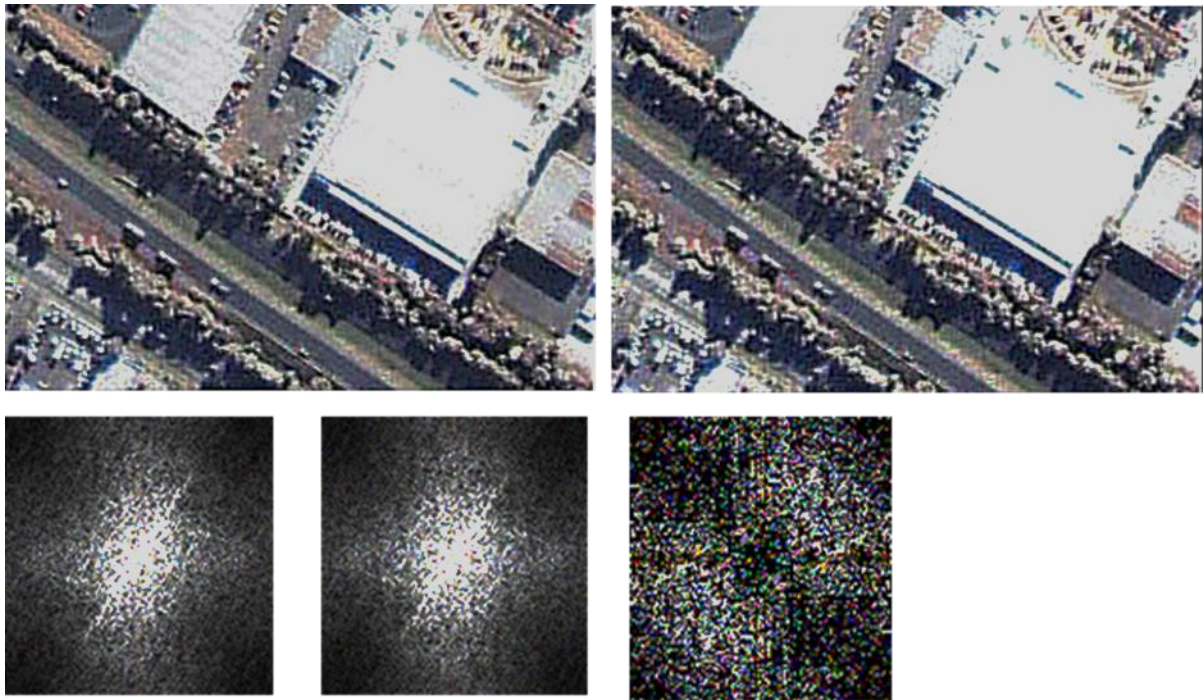
Fig. 3. Original image with resolution correction (top left); corrected image (top right); spatial frequency spectrum of the original image (bottom left); spatial frequency spectrum of the corrected image (bottom center); difference spectrum (bottom right).

Conclusions:

The requirements introduced in the work to fulfill the conditions of the multiplicative form $\beta\omega^\beta \ll 1$ are the starting ones for image correction with an increase in the contrast level of the image counts with the exclusion of almost completely nonlinear transformations.

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