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Valorization of the Noise Content in Photogrammetric Images Using Wavelets**

1. Introduction

One of the digital image advantages is their simple structure consisting in mapping of a region, an object or a phenomenon onto the plane divided into elementary squares – pixels The imperfections of the raster modeling of reality are compensated by access to the wide spectrum of digital images processing methods, being developed in many scientific fields It is worth to note the large efficiency of the raster solutions in the data transfer. This is clearly seen in the Internet, where the user is often not aware of how large are the files from which the images visualized on the screen are made.

In spite of the huge progress in the image processing, not all operations give satisfactory results The detecting of edges can be an example. This is very effective for the images with high contrast and simple content, but considerably less effective for the multitonal images of natural scenes This example was given because the edges detecting occurs, directly or indirectly, in the most of the methods automating the image processing in the photogrammetric technology (for instance, in automatic aerotriangulation and automatic generation of the data for NMT constructing). The radiometric quality is often neglected when looking for the reasons of the unsatisfactory quality of the automatic images analysis Meanwhile, the image noise can substantially reduce the efficiency of image processing, especially in the case of images with low contrast and containing many fragments with fine-grained structure, with which we deal often in photogrammetry and remote sensing.

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2. Image Noise

Image noise together with radiometric resolution, contrast, tonal matching are elements shaping radiometric quality. Noise is any random or deterministic disturbance of luminance of a hypothetical image that would come into existence in the ideal conditions [2]. Noise arises in the different stages of the image acquisition: during the image forming, sampling, encoding, compression, transmission and during image processing. Image noise can have a deterministic or random character.

2.1. Deterministic Noise

During the investigation of noise content in the image, first of all, the places of noise occurrence should be detected and the noise character should be determined. Most often, we are left to visual estimation, which aim is to put forward a hypothesis concerning the spatial distribution of the noticed interference. This, in its turn, helps to determine the reasons of their occurrence and to formulate the deterministic model of radiometric distortions.

Periodic noise can be detected relatively easy, especially when it occurs in the whole image or in the large image fragments The classical example of such a noise is image striping, where stripes with constant interval between them arise as a result of scanner imperfections or transmission interference. If these disturbances are connected with the signal (dark or light stripes but carrying the image information) then it is possible to remove defects completely. When the stripes are black or white (do not carry the image information) then it is possible only to whitewash the defect by fulfilling the missing places with average values from the adjacent image lines Besides the linear disturbances, the sinusoidal and point disturbances occur often as well.

Visually, the phenomena of image darkening at the periphery could be also noticed, especially when there are wide-angle lens in the image forming system (vignetting). Because the phenomenon has a radial character, it is possible to model it with the high accuracy and – as a consequence – to remove the disturbance [3].

2.2. Random Noise

Random noise is present practically in any image, but is not always noticed. In the analog images, the source of random noise is the granular structure of photographic emulsion. Noise in the digital images is caused by instability of detectors, including – to some extent – detector's own noise. Another source of random noise is image processing itself. An example is rounding of brightness values to integers, in which the image brightness is encoded, during the numerical operations.

Random noise, because of its unpredictable character, cannot be removed completely from the image. One can only smooth over the effects of its occurrence. The most popular method of noise removing is context low-pass filtering. All low-pass filters reduce the noise level but simultaneously wash out the edges present in the image. We face a dilemma: Is it better to reduce the noise level at the expense of the edges sharpness or the other way round? A compromise is applying the filters, which detect the edges in the first stage and next protect them against the destructive action of averaging made for the pixels placed outside the edges [7]. This solution is regard as the most advantageous, but it does not remove the following disadvantage: The poorly visible edges may be undetected because they are "obscured" by noise. As a consequence, the poorly visible edges will be averaged compared to their context and because of that they will be weakened.

The described methods of noise reduction work well for the images with high contrast. In photogrammetry and remote sensing the landscape images taken from large distances predominate. This together with high radiometric resolution results in the multitonal pictures with low local contrast and small signal-to-noise ratio. This is why there is a need to look for the indicators of noise content.

3. Basic Features of Wavelet Transformation

Wavelet transformation demonstrates some features shared with Fourier transformation and this is why it is often compared to the latter. Both transformations transform the signal from spatial domain into frequency domain. In both transformations the basis functions, called supports, are defined and their linear combination forms the frequency representation. The Fourier supports, that is, the sinusoidal functions, are as long as the domain of the described function (they can be vividly defined as the infinite waves at sea.) On the other hand, the wavelet transformation uses the short supports, small wavelets, which only in short segment are substantially different from zero and in the rest segment, considerably longer, are equal to converge to zero (they can be compared to waves arising locally at lake). The wavelet transform is a frequency-spatial representation, i.e. it is possible to localize each coefficient spatially, what is impossible in the case of Fourier transform. Wavelet transformation is a frequency-spatial representation, i.e. each coefficient can be spatially located.

The procedure for determining the image wavelet expansions (two-dimensional signals) with the help of multistage decomposition utilizing one-dimensional filters, separately applied to the rows and columns of the image, was given by [1]. There are four components in the wavelet expansion of the image: so-called coarse component (LL) and three details, named as vertical (LH), horizontal (HL) and diagonal (HH) detail. They are shown in figure 1. The characteristic feature of wavelet transformation is the possibility to continue applying it to the chosen component. This is the coarse detail that is expanded most often.

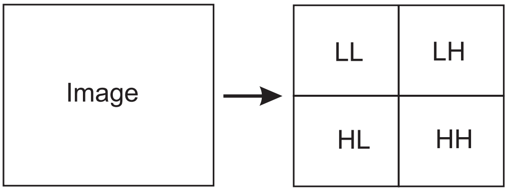

Fig. 1. The four components in the wavelet expansion (wavelets components)

Visual estimation of the wavelet component allows detecting the artifacts, which are not visible during the inspection of the image in the classical form. The destructive effects of the lossy compression with the help of JPEG algorithm are more easily noticeable in the diagonal detail (HH) than at the observation of the image in the classic form [4].

4. Random Noise Valorization by Means of Wavelet Component Analysis

The wavelet representation of the image can be also used for evaluation of the image radiometric quality, including the random noise present in it. This was proposed first time by Simonceli [5, 6], who noticed that wavelet detail coefficients distribution has a sharp maximum in zero and has a good symmetry, whereas the flattening of histogram is correlated with the presence of noise in the image. In figure 2 the typical histograms of four wavelets components are shown.

Simonceli's hypothesis, based on the analysis of wavelet components of the typical scenic ground photographs, was confirmed for aerial and satellite photographs, too. In the paper [4] the author analyzed the aerial photographs of different grounds, taken in different scales, and high resolution satellite images He proposed to employ kurtosis, which is the fourth moment divided by the square of the variance, as a parameter describing the histogram shape. Three representative cases of the wavelet coefficients distribution were assumed: normal distribution for which kurtosis equals 3, Laplace distribution, more peaked than normal distribution, with kurtosis equal to 6, and modified (symmetric) gamma distribution, even more peaked, with kurtosis equal to 12. In figure 3 the normal, Laplace and gamma distribution curves are shown.

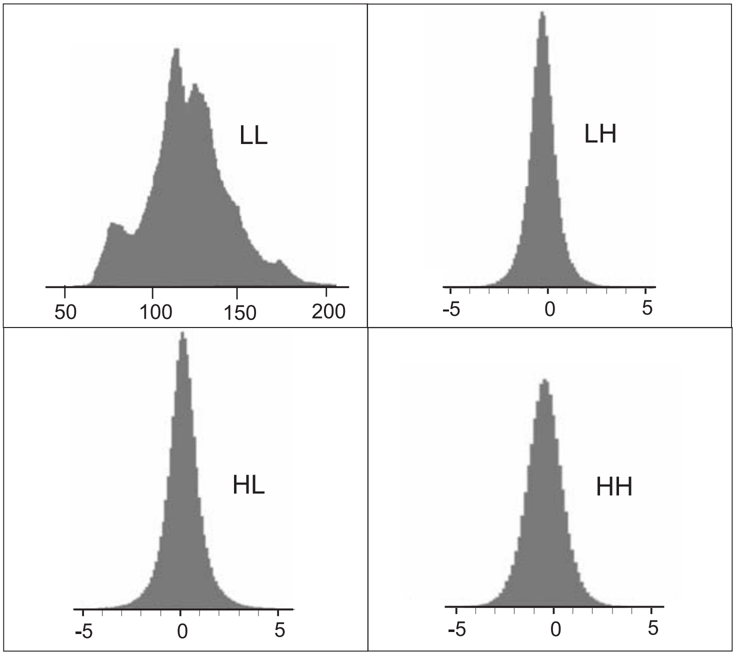

Fig. 2. Histograms of the wavelets-components

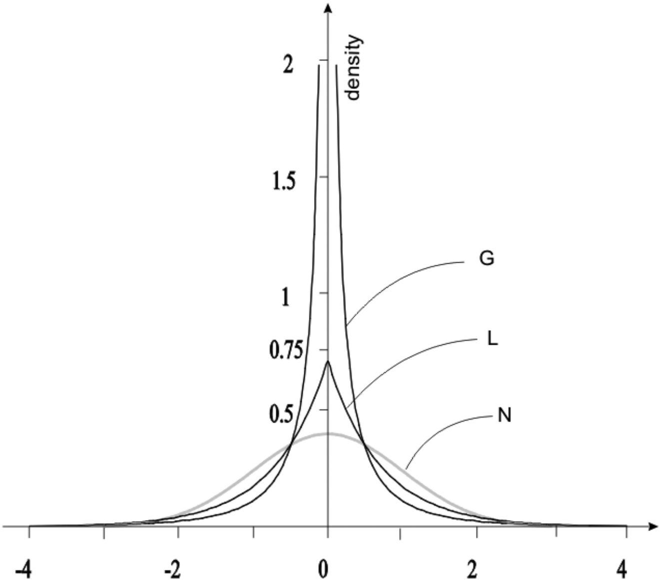

Fig. 3. The normal (N), Laplace (L) and gamma (G) distribution curves
Source: [4]

In the paper [4], the strong correlation between random noise content in the image and the shape of wavelet expansion detail components distribution was confirmed. It was noticed that the correlation between the distribution and noise can be disturbed in these image fragments where a natural fine-grained structure is present. This is why only these image fragments where the natural structure is smooth, spotty or coarse-grained in the last resort, should be chosen for analysis Simultaneously, it was claimed [4] that the estimation of the shape of coefficients distribution should be made for all three detail components, but it is enough to limit research to wavelet decomposition on one level of resolution. Further decomposition of coarse component (LL) does not give more information on noise, because each subsequent coarse component is the effect of the smoothing of the preceding one, what decreases the noise content.

Simulation of the wavelet component histogram shapes can be employing for comparison of the radiometric changes occurring during the images processing. Analyzing of the wavelet coefficients histograms of the source image and processed one it is possible to estimate the degree of image smoothing. If the goal is noise reducing then the histogram should be more peaked than the histogram of the source image. If the processing has a geometrical character (e.g. orthophoto rectification) then the large change of the details histogram shape indicates excessive radiometric changes, caused, for instance, by choose of the wrong function for brightness interpolation of the generated image [4].

In the current stage of research it is not possible to use the results of the wavelet-components distribution simulating as an absolute measure of the noise content. Defining such a measure requires carrying out a series of experiments, in which the images with different scales (with different pixel sizes) representing the different ways of area using and area covering, taken in the different seasons, will be studied.

5. Conclusions

Valorization of the noise content was based on the observation given in literature, stating that the noise changes the shape of the transform detail components histograms.

The investigation made proved the usefulness of the valorization for the comparative analysis of the images of the same scene taken at the same conditions In practice, such a situation occurs rarely, but it is possible to compare the noise content between the image and its radiometric or geometric transformation (the change of geometry is always accompanied by the brightness interpolation). Such an analytical tool allows controlling the degree of image smoothing, because the quantitative, relative indicator of noise level is at one’s disposal.

In the current stage of research it is not possible to propose the analysis of wavelet coefficients distribution as an objective quantitative measure of image noise level. However, the experiences from the experiments carried out so far are so promising that it is worth to continue the investigations on the research material registered in the different scales, in different seasons, using digital and analog camera.

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