Revealing of digital images assembling on the basis of maximum coefficients analysis of wavelet transform

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Summary. The method to reveal the assembling of media-data based on wavelet decomposition with the analysis of frequency components of signal decomposition is proposed.
Key words: media-signal, wavelet decomposition, assembling, information technologies.

INTRODUCTION

The task to improve methods of digital signal processing in general, and methods of revealing the objects of media-data modification in particularly is one of the most important tasks in many fields of science and engineering: forensic science, images, video and sound processing, data confidentiality and so on. In this case this work is very relevant because the spheres are being widened due to new methods. The methods of revealing, introducing a new theoretical and algorithm basis, using new reveal methods at the level of apparatus and programmed means which support a computing process [17, 18].

The tasks to evaluate the authenticity are one of the most important tasks in forensic science expertise. Rapid development of methods to evaluate the authenticity of a digital signal has given the rise to a great number of different approaches and algorithms to solve the tasks in this field for the latest 10 years [1, 5, 6, 19].

Proposed methods and algorithms in the most cases have eureka nature and use this or that statistic peculiarity of a digital signal. As a rule, such statistic peculiarities are the result of empirical facts and regularities which seldom claim to be enough general, universal by nature [9, 10, 18, 20].

Practically there are no approaches solving the tasks concerning the evaluation of digital signal authenticity on the basis of a single physical model and consequently there is no mathematical approach in references. At the same time the construction of stable algorithms for authenticity evaluation, their checking, testing and solving of return tasks demand to create and develop consecutive physical and mathematical models of digital graphical signals.

Analyzing the regularities in a signal there is a possibility to evaluate data unity on the basis of the analysis and to single out characteristic features of regularities characteristic the device of signal formation. Creation, encoding and presentation of multi-media data constitute a unique signal with definite statistic characteristic features. [7, 8, 12]. The analysis of this signal for the purpose of its characteristics changes is the basis for conducting the research to reveal its modifications [3, 4, 16]. To guarantee that received data haven't been processed by proper people it is necessary to evaluate given characteristics identifying each of the steps, receiving, initial encoding, channels encoding, and transmission. Each of theses steps as a rule brings unique components to an exit signal and these components are the part of the authenticity system.

METHODS OF RESEARCH

Raster graphic files as the elements of media-data are considered in this work.

In our research we take into account such main characteristics of researched methods in order to reveal the modifications of images as: versions, possibilities regarding space and large-scale change, localization of geometrical sizes and objects coordinates, noise resistance, localization and revealing signal properties, availability of fast computing algorithms, adaptation to peculiarities of analyzed data.

Specific methods are used to reveal computing complexes of signal processing in the form of media-data in compounds, they are also used to reveal the availability of great demands to their adaptation, noise resistance, work speed and the possibility of a data multi-profile analysis. And a specific of applied methods requires the development of a new method which meets above-mentioned requirements. According to all this the analysis of modern methods to reveal the objects of artificial origin have been done, their classification have been performed, their main advantages and drawbacks have been revealed.

On the basis of carried out analysis the evaluation method of media-data authenticity has been proposed, it has been based on the wavelet-analysis means and has been aimed at signal complex processing including: defining the best decomposition basis, wavelet filtration by adaptive thresholds, division into the fields of probable location of searched objects, singling out characterized space and large-scale properties and vectors signs, the initial classification, and also making classification more precise by using a fractal analyzer.

Synthesize the revealing procedure of vectors characteristic features of objects analyzed graphical signals on the basis of wavelet-analysis means.

Wavelet transformation is a presented signal invariant regarding a (shift) change. At every scale ***s*** at the function shift $f(t)$ by value r, wavelet coefficients $Wf(u,s)$ are also shifted by r. Shift takes place, occurs naturally and separately singled out wavelet maximums generated by the peculiarities of an analyzed signal. Such a property allows us to build much simpler and fast-acting revealing and classification algorithms than in the case when a transformed signal depends on the location of its structures.

The property of invariant wavelet transformation comes from its interpretation as operation of convolution:

$$\begin{aligned} &Wf(u,s) = f\psi_s(u) \Rightarrow \exists(t) = f(t-r) \Rightarrow \\ &\Rightarrow Wf(u,s) = f * \psi(u) = WF(T-\tau,s). \end{aligned} \quad (1)$$

In this case there is one problem. It is error accumulation in shear on a uniform discrete net. If a sample pitch is small the convolution indications (1) are approximately approaching at the function shift $f(t)$, however resulted discrete net for W, f (u,s) can not coincide by indications with the net W, f (u,s). The only way out of this situation is to use adaptive schemes of a sample when a discrete indication grate is automatically shifted in a signal shear changing by this the location of wavelet coefficients, and respectively the location of their local maximums.

Wavelet transformation is able to focus on the local structural signals with the help of approaching and distancing procedures based on the alteration of large-scale transformation parameters. At the same time it is known, that these are peculiarities and rough structures which contain main information about a signal, that is particularly those peculiarities on the basis of which different objects presenting in signals can be identified as assembling elements.

To characterize structures with peculiarities (ruptures, regularity disturbance, space-frequency composition and so forth) logically it is necessary to define exact importance of signal smoothness at time intervals and at any point with the help of Lipshits index [2].

If $f(t)$ has a peculiarity at $t = v$, which means that the function un-differentiated at this point, Lipshits index at $t = v$ characterizes function singled behavior. In such a case, Lipshits index having the value $a < 1$ at the point v allows defining the peculiarity nature.

And vice versa, if $f(t)$ satisfies Lipshits uniform conditions $a > m$ in the vicinity of v, so it is by all means m times continuously differentiated in this vicinity.

For points on the surface of wavelet transformation let's rewrite Lipshits smoothness condition as an inequality:

$$\left|Wf(u,s)\right| \le As^{a+1/2}. \qquad (2)$$

To define exact value of Lipshits index let's take the logarithm of both parts of an inequality 2:

$$\log_2\left|Wf(u,s)\right| \le \log_2 A + \left(a + \frac{1}{2}\right)\log_2 s. \qquad (3)$$

Lipshits smoothness in this case is determined by maximum inclination $\log_2\left|Wf(u,s)\right|$ as the function $\log_2 s$ along the line of maximums converging to v, or point-wise according to the following formula:

$$a \ge \frac{\log_2\left|Wf(u,s)\right| - \log_2 A}{\log_2 s} - \frac{1}{2}. \qquad (4)$$

As a result we can come to the conclusion that the usage of wavelets maximums as an "element" of local smoothness $f(t)$ is an effective mean allowing us to receive additional information characterizing an analyzed object.

Besides, the singling out of module wavelet coefficients maximums automatically singles out not only the disturbance of signal local smoothness but allows localizing the peculiarities of function $f(t)$, and also allows defining their nature, character.

Signal peculiarities are singled out by means of abscess finding out in which maximums of module coefficients wavelet transformation at a small scale are converged. The ability of wavelet transformations to single out peculiarities is revealed at its interpretation as multi-scaled differentiated operator. It is proved in [2] that if wavelet $\psi = (-1)^n \theta^{(n)}$ has n zero moments and a compact carrier, the wavelet transformation $Wf(u,s)$ can be re-written by the following way:

$$Wf(u,s) = f * \psi_s(u), \qquad (5)$$

where: $\overline{\psi}_s(t) = \frac{1}{\sqrt{s}}\psi\left(\frac{-t}{s}\right).$

As $\psi(t) = (-1)^n \frac{d^n\theta(t)}{dt^n}$ then:

$$Wf(u,s) = s^n f * \frac{d^n\overline{\theta}_s(t)}{dt^n} = \\ = s^n \frac{d^n}{du^n}\left(f * \overline{\theta}_s\right)(u). \qquad (6)$$

If analytical wavelet has only one zero moment, maximums wavelet transformations are interpreted as maximums of the first-order derivative of function $f(t)$, smoothed out by the nucleus $\overline{\theta}_s$. These are maximums which define the location of ruptures and signal differences. If analytical wavelet has two zero moments, the maximums of module wavelet transformations correspond to the greatest curvatures.

Besides the wavelet maximums locations allow localizing the differences of an analyzed signal. Some segment boundaries can change their location or they can completely disappear with the alteration of large-scale signal presentation that is with the motion along the structure of decomposition / restoration.

Naturally the boundaries of an object outline *C(u,s)*,presented by wavelet coefficients of a peak amplitude “are seen” on a great number of scales. The boundaries presented by the coefficients of small amplitude are only seen on a limited number of scales. So, as an additional object or a segment characteristic feature it is possible to single out its scale limit $j^k_{\max}$, that is the number of decomposition level where the outline is disappearing or converging.

Such a given parameter additionally characterizes the sizes of an analyzed objects and multi-scaled wavelet transformation reaction influencing it. To use this feature as a limit also permits additionally to divide the set of standard objects by the limits of their scale visibility.

Such features of maternal wavelet functions as a number of zero moments and the carrier width play extremely important role for localization and singling out signals peculiarities.

The majority of wavelet functions have a compact carrier that is some interval (a,b), for which $\forall_t \notin (a,b) \Rightarrow \psi(t) = 0$ is performed. However, if wavelet hasn’t this property, the interval with smearing boundaries is defined where $\psi(t) \approx 0$ and on which the carrier can be considered to be compact. The carrier width defines sizes of frequency-time (slot) window formed by wavelet in the time range.

Different wavelet functions have various numbers of zero moments. It is said that wavelet $\psi(t)$ has n zero moments if for any $k < n$ the following condition is performed:

$$\int_{-\infty}^{\infty} t^k \psi(t) dt = 0 . \qquad (7)$$

Wavelet with n zero moments is orthogonal to a polynomial of degree $n-1$, and this value n defines the wavelet sensitivity to a signal irregular polynomial components.

If an analyzed signal $f(t)$ has a feature at the point t_0 and if t_0 is inside of the carrier $\psi_{j,n}(t) = 2^{-j}\psi(2^{-j}t - n)$, so wavelet coefficients $\langle f, \psi_{j,n} \rangle$ have great amplitude.

The size of a carrier function and a number of zero moments are a priori independent. However, limits put on orthogonal wavelets mean that if wavelet function ψ has p zero moments, so the least carrier exists which is equal to $2p-1$. For example, Dobeshi Wavelets are the most optimal in this sense because they have a carrier minimum size at a given number of zero moments.

If $f(t)$ has some isolated features, peculiarities and the interface is very smooth between them in this case it is necessary to choose wavelet with more number of zero moments in order to receive a great number of small wavelet coefficients $\langle f, \psi_{j.n} \rangle$. If density of features is increasing, so it is better to reduce the size of the carrier due to the reducing of a number of zero moments.

Naturally, there is no single, unique basis which is ideally corresponding to present all types of signals. Moreover, it is rather difficult to define what type of wavelet functions is better to be used for one particular analyzed signal. Such a feature of used theoretical base creates some difficulties, however, if it is correctly, professionally used it gives the possibility to adapt to the maximum signals wavelet presentation to their physical essence [2].

Considered approach allows singling out the differences of an analyzed signal, and also the outlines which are on the objects images. While doing investigations the statistical characteristic features of singled out objects outlines have been evaluated. Singled out features permit uniquely to determine geometrical features of objects, their scaled “visibility”, allow singling out the composition of signal features and their nature (character) depending on the nature of analyzed signal. To improve singling out the signal features connected with assembling the filtration on the basis of a fractal analyzer according to the algorithm has additionally been done [2].

RESULTS OF RESEARCH

A number of experiments to check the creation of an approach to reveal the assembling of digital images have been done.

During the experiments model signals the features of which are approaching to the maximum to the features of researched processes have been synthesized. Signal modeling have been performed in Simulink area of Matlab packet by means of simulation of digital device recording graphical signals on the basis of algorithms choice characteristic to the operations of transformation analogue graphical signal into digital one.

Modeling of characteristic feature (singularity) has been done on the basis of the following propositions. Time extent of singularity $Z^j{}_k$, connected with assembling is a random quantity having uniform distribution at interval $\lfloor t_j, t_{j+1} \rfloor$. Singularity height is also a random quantity having uniform distribution at interval $\lfloor a_j, b_j \rfloor$.

During the process of model signal formation the time interval $\Delta t = t_{j+1} - t_j$, contains singularity and takes values from 2 till 120, and the height of singularities $\zeta_{i,j}, i = \overline{1{,}3}$ takes the value beginning with the level of background (hum) variations and ending with the value exceeding background level twice.

Researches to evaluate the effectiveness on the basis of models of main hum (backgraound) and the object have been done. Necessary parameters and corresponding criteria of evaluation to fulfill the effectiveness analyses have been considered. The research methodic based on the features of proposed revealing method is presented. It is stated that in order to determine the values of identification quality and to calculate the features of finding out the assembling of digital graphical signal instead of the values signal-to-noise ratio (in this case it is possible to speak about the relation “hum-to-signal ratio) here advisably to use ratio of singularity square to window square, that is Sc/S window.

Testing the proposed theoretical statements 6 main types of digital images assembling have been considered with the exception of the replacement of a recording mechanism print (which has been considered apart). Looking at a given drawing (Fig.) we can see that average probability for different types of assembling to reveal modifications of digital signal (DMS) is more than 95% and it is achieved already for signals with ratio signal-to-noise more than 15 dB.

It permits to come to the conclusion that for the truth of a signal the most important signal features are those which are singled out on the basis of model detailed components. Besides it proves the universality regarding to different variants of digital images modifications, high noise resistance (immunity), and performance in terms of error probability, the method of revealing and its high efficiency for signals with quality “lower than average"has been proposed.

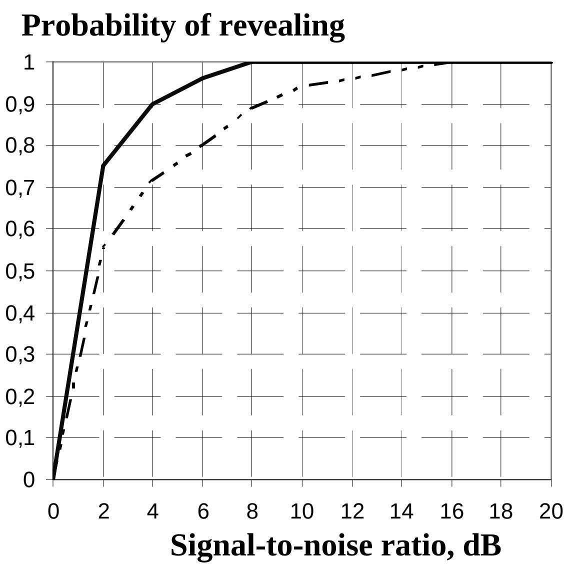

Fig. Graph of dependence of average probability for revealing the features in the assembling area against “signal-to-noise” ratio of digital image

model without fractal analyzer,
model with fractal analyzer

CONCLUSIONS

1. Methods and means used in modern practice to evaluate the authenticity don’t provide the guaranteed revealing traces of digital processing of digital media-data and the

identity between digital graphical signal and the device of its formation.

2. While carrying out the research the model to reveal the assembling of digital image by means of evaluation the distribution of outlined features in the structure of digital image on the basis of maximum wavelet decomposition has been developed, this model proved its efficiency in the process of creation the system for revealing assembling image.

3. Algorithms of singularity classification characteristic to the assembling in the structure of digital graphical signal have been developed and investigated. On the basis of model signals processing it is shown that the developed algorithm permits to reveal large-scale singularity with the probability of amplitude 0, 98, exceeding background level by 1, 1 times.

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ВЫЯВЛЕНИЕ МОНТАЖА ЦИФРОВЫХ ИЗОБРАЖЕНИЙ НА ОСНОВЕ АНАЛИЗА МАКСИМУМОВ КОЭФФИЦИЕНТОВ ВЕЙВЛЕТ-ПРЕОБРАЗОВАНИЯ

Евгений Белозеров

Аннотация. Рассмотрены вопросы оценки подлинности цифровых изображений. В качестве элементов оценки подлинности предложено использовать структурные особенности изображений различной формы и протяженности, связанные с устройством записи изображения. Рассмотрен метод выявления структурных особенностей на основе вейвлет-декомпозиции сигнала. Предложен метод выявления монтажа медиа-данных, основанный на анализе частотной составляющей вейвлет-декомпозиции изображения.
Ключевые слова: медиа-сигнал, вейвлет декомпозиция, монтаж, информационные технологии.