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Method for identification the recording device of digital images

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S u m m a r y . The method to reveal isolated features in digital image connected with its recording device is proposed. The algorithm of signal decomposition on the basis of wavelet analysis is given, the identification criteria of isolated features in the image structure are singled out. The identification algorithm of a recording device of digital images on the basis of the usage of singled out isolated characteristic features has been developed. Experimental research to estimate the accuracy of identification of digital images recording device has been done.

K e y w o r d s : an image, spectral characteristics, wavelet decomposition, isolated features.

INTRODUCTION

Research and development of instrumental means to control multi-media data, integrity authenticity both the data themselves and the device identification for media signal formation became very relevant due to their usage as a proved basis in forensic medical agencies and so on [16, 20]. It is necessary to note that at present multi – media data as evidence play a secondary role due to the lack of necessary means for the analyses of their authenticity, integrity and correspondence with the device forming the signal.

Identification of the formation media signal source is one of the most important and very solved- difficult tasks in the aspect of authenticity media- data estimation. There are several approaches to solve this problem. The problem of the source identification has been studied in works [9, 1, 2] for images groups having been received from several cameras under controlled conditions. In work [8] the authors have offered the method to identify separate imprints of image sensors on the basis of additive noise (PRNU). Earlier K. Kurosawa has offered a unique method of video-camera identification with the help of defective pixels in CCD sensors [14, 18, 19]. In work [21, 9] the identification of camera source has been researched for two different cameras using additional links (connections) during charge transition for CMOS sensors. The authors have shown that their method reveals the camera-source with high accuracy even for images taken in a wide light range. There are some well-known works [10, 11, 13, 15] which deal with the division of sources forming the images into classes. However, it is necessary to mention that none of the described methods possess high enough revealing accuracy to be used as a proved base.

Thus, the aim of the work is the research and the development of authenticity method for the device forming digital images on the basis of the analysis of apparatus noise characteristic features.

METHODS OF RESEARCH

Recorded digital data of a digital image is presented as a sequence of its amplitude readings which are the result of interaction of two components – the first one is a recorded scene and the second component is apparatus disturbances. If statistical characteristics of these two components were approximately equal it would be senselessly to set a task of dividing signal and disturbances. However, it is known that in a majority of important cases frequency responses of signals and disturbances are separated. Apparatus disturbance power is localized mainly in a high- frequency range in comparison with a signal [8].

From the point of view of modern conceptions digital images in any random section represent themselves a set of different self-similar formations both at the level of outcome scene and at the level of disturbances. It can be supposed that self-similar structures characterizing the scene will be changeable over a period of enough represented images sample received from the same formation image device [6]. At the same time, from physical thoughts it is evident that formations responsible for characteristic features of formation images devices must possess more stable characteristic features over a period of enough great images sample received from one formation images device.

The researches of graphical files show the availability of a great number of high-frequency bit structures of “special kind” the number of which in different fragments of the same file greatly differs from accidental one [7]. Here, stable regularities in the distribution of such structures by the same digital image are watched. This fact is the evidence of the existence of self-similar multi- fractional images in the elements of graphical files. These formations can be matched up the statistical features which are the results of hidden regularities in the device of a digital image formation [6].

Let’s consider the algorithm of revealing features in the image structure on the basis of wavelet transformation.

Wavelet is a transformation which arranges the signals by extended and shifted wavelets ψ. As wavelet ψ has a zero mean value, so wavelet is an integral which:

$$Wf(a,b) = \int f(t)\frac{1}{\sqrt{a}}\psi\left(\frac{t-b}{a}\right)dt, \quad (1)$$

measures the change f in the range of point b, the size of which is proportional to a. While the scale a is striving for zero the wavelet–coefficients characterize properties of function f in the vicinity of a point b. If function f by m times is differentiated by $[v-l; v+l]$ and $\rho_v(t)$ - is Tailor polynomial in the vicinity of v, then:

$$\rho_v(t) = \sum_{k=0}^{m-1}\frac{f^{(k)}(v)}{k!}(t-v)^k. \quad (2)$$

The error of such an approximation $\varepsilon_v(t) = f(t) - p_v(t)$ satisfies the condition:

$$\forall t \in [v-l; v+l].$$

$$\left|\varepsilon_v(t)\right| \le \frac{|t-v|^m}{m!}\sup_{u\in[v-l;v+l]}\left|f^m(u)\right|. \quad (3)$$

The order of differentiability f in the vicinity of v determines upper bound of error $\varepsilon_v(t)$ at t striving for v. Lipshits smoothness makes more precise this upper bound introducing non-integral index on the basis of the following definition.

In work [17,12] it is shown if wavelet ψ has n zero moments, that is:

$$\int_{-\infty}^{+\infty} l^k \psi(t)dt = 0, k = \overline{0;n-1}, \quad (4)$$

and n derivatives, then for $f \in L^2(R)$, satisfying uniform Lipshits condition $\alpha, \alpha \le n$ at $[a,b]$, $A > 0$ exists, that:

$$\forall (s,u) \in R^+ \times [a,b] |Wf(s,u)| \le As^{\alpha+1/2}. \quad (5)$$

Inequality (5) is the condition of asymptotic decreasing of $|Wf(s,u)|$ at $s \to 0$. Thus, the decreasing of wavelet-transformation amplitude depending on the scale is connected with uniform and pointed smoothness of Lipshits signal. Inequality (5) can be rewrited:

$$\log_2 |Wf(s,u)| \le \log_2 A + \left(\alpha + \frac{1}{2}\right) \log_2 s. \quad (6)$$

Lipshits indexes can be arbitrarily changed from point to point. To characterize the smoothness f at point v is rather difficult because f can have different types of features presenting in the vicinity of point v. Zhaffar's theorem gives necessary and essential condition to wavelet transformation to estimate smoothness of Lipshits function f at point v.

Let wavelet ψ have n zero moments and n derivatives. If $f \in L^2(R)$ satisfies Lipshits condition $\alpha \le n$ at point v, then A exists that:

$$\forall (s,u) \in R^+ \times R,$$

$$|Wf(s,u)| \le As^{\alpha+1/2} \left(1 + \left|\frac{u-v}{s}\right|^{\alpha}\right). \quad (7)$$

That's why when scale s is diminishing the amplitudes of wavelet coefficients have fast diminishing till zero in the range where the signal is smooth.

Cone of influence of point v represents clearer interpretation of the condition [17].

If wavelet ψ has a compact carrier equal to $[-C, C]$, then the majority of such points (s,u), that point v contains $\psi_{u,s}(t) = s^{-1/2}\psi((t-u)/s)$, in the carrier, and these points determine the cone of influence of point v of a large – scale surface. As the carrier $\psi((t-u)/s)$ is equal to $[u - Cs, u + Cs]$, then cone of influence v is defined by the inequality:

$$|u - v| \le Cs.$$

If u is in the cone of influence v, then $Wf(s,u) = \langle f, \psi_{s,u} \rangle$ depends on value f in the vicinity of v. As $|u - v|/s \le C$, so the conditions (5) and (7) can be written in the form of:

$$|Wf(s,u)| \le As^{\alpha+1/2}, \quad (8)$$

what: is identical to uniform Lipshits condition.

Let's consider that function f in the vicinity of point v has an isolated feature, if $|Wf(s,u)|$ doesn't satisfy the condition (8) in the vicinity of point v.

The results of work [17,3] are the following, if $|Wf(s,u)|$ hasn't local maximums in small scales then f is a locally smooth function and the operation of singling out of isolated features of function f can be built by defining maximum values of function $|Wf(s,u)|$ in small scales. Here it is necessary to take into account that while processing discrete data the smallest scale is limited by the step (pitch) of a discrete signal sample which is used during calculations.

When a feature is singled out there is a task to classify it.

Let's build the operation of classification of singled out features in a signal on the basis of inequalty (6) by the following way:

Denote $O_v(s,u)$ the line of maximums converging to point $u-v$, at $s \to 0$. For every such a point v determine slop angle $\log_2 O_v(s,u)$ as function $\log_2 s$, at $s \to 0$:

$$\log_2 O_v(s,u) = \log_2 A + \left(\alpha + \frac{1}{2}\right)\log_2 s\,. \quad (9)$$

Let's consider that we have a feature of $\alpha`$ at the point $u = v$.

Here it is necessary to take into account that the solution of the task to classify the peculiar feature depends on the basic function ψ properties. The set of features of a graphical signal received by such a way represents itself a pattern camera which can be used for its modification.

Experimental estimation and the analysis of the reaction of classification standard procedures on the feature of data presentation in the offered revealing procedure, their dependence on characteristics of processed signals presented in the form of large-scale decomposition structures and processed by means of wavelet analysis have been carried out in this research [4,5].

While carrying out the research of the revealing of additive noise characterized for a number of digital cameras on the basis of a considered algorithm singling out for revealing isolated features of images has been done. Typical graphical patterns and maps of particular points which are characteristic to the formation image device have resulted of this performed research.

The cut off threshold of detailed coefficient close to optimum and the efficient decomposition depth equal to 4 has been chosen for data wavelet processing.

Checking, testing of the algorithm search for particular points in digital image which are characteristic to the device of its formation has been done on the basis of the following stages:

Receiving a great number of images from the camera forming the sample for design, construction of camera print.

The stage of camera print receiving on the basis of a great number of images from the identified camera of camera print. This stage includes the revealing from the print of pattern camera with the help of described filtration algorithm and its averaging by all prints from the sample premeditated for vector features formation.

The stage of image identification by camera pattern (Fig.).

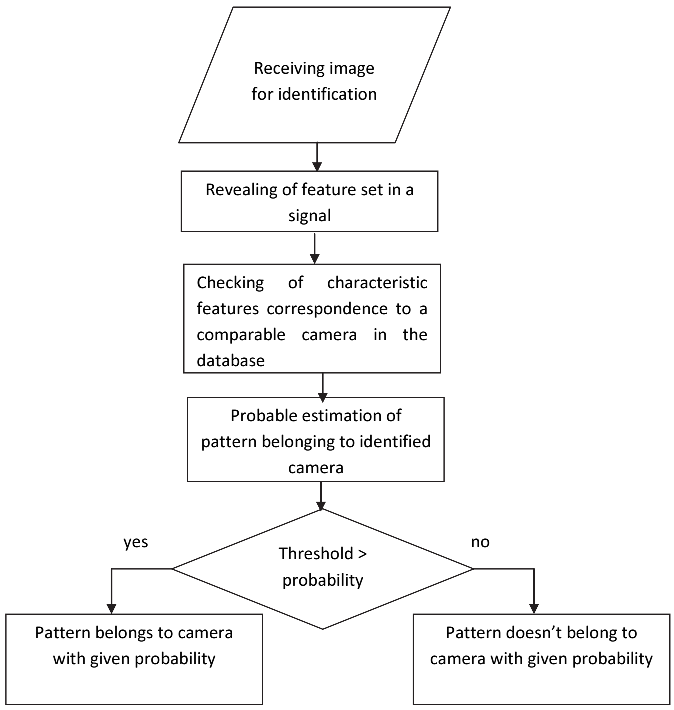

Fig. Algorithm of camera identification by formed print

Table. Values of averaging correlation coefficients results of received camera patterns

Camera	1	2	3	4	5	6	7	8
1	0.1364	0.0003	0 0018	0 0004	0.0017	0.0020	0.0030	0.0023
2	0.0004	0.1889	0.0002	0.0007	0.0004	0.0009	0.0000	0.0003
3	0.0035	0.0000	0.1727	0.0025	0.0042	0.0024	0.0044	0.0022
4	0 0004	0.0000	0.0015	0.1423	0.0006	0.0001	0.0016	0.0009
5	0.0005	0.0001	0.0010	0.0001	0.2645	0.0012	0.0010	O.0008
6	0.0009	0.0001	0.0004	0.0001	0.0005	0.479	0.0000	0.0012
7	0.0046	0.0001	0.0031	0.0018	0.0027	0.0029	0.1238	0.0017
8	0.0031	0.0002	0.0023	0.0015	0 0017	0.0032	0.0025	0.2005

RESULTS OF RESEARCH

Eight cameras model Nikon D5100 have been used for experimental checking of offered algorithm. 50 photos from each camera have been done for receiving camera prints. After singling out particular points the relationship of a number of such coincided points with a pattern received from the camera has been compared. The results of averaging correlation of received camera patterns are given in table. The coefficients of images and patterns received from the same camera are at the columns and lines intersection with the same indexes. Thus if the matrix with the help of which the image and the map of non – uniformity coincides, the coefficient correlation value is 0.1 – 0.4 but at the coefficient correlation for non – coincided cameras it is 0.001 – 0.054.

As it has been stated while doing the experimental research similar regularities of coincided points the distribution in a pattern camera are kept for all researched cameras. Thus, on the basis of coincidences relationship we can come to the probable conclusion that researched photo belongs to a particular image formation device.

CONCLUSIONS

1. Carried out research allowed us to single out and identify formations in digital images (pictures) characteristic to the formation signal device.

2. The estimation of device identification authenticity on the basis of a proposed algorithm is satisfactory but not sufficient for the given algorithm usage as a part of a proved base.

3. Due to it is necessary to consider the ways to improve the proposed algorithm in further researches.

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МЕТОД ИДЕНТИФИКАЦИИ АППАРАТУРЫ ЗАПИСИ ЦИФРОВЫХ ФОТОГРАФИЙ

Николай Сидоров, Евгений Белозеров

Аннотация. Предложен метод выявления в цифровом изображении изолированных особенностей, связанных с устройством его записи. Приведен алгоритм декомпозиции сигнала на основе вейвлет-анализа, выделены критерии идентификации изолированных особенностей в структуре изображения. Разработан алгоритм идентификации устройства записи цифровых изображений на основе использования выделенных изолированных особенностей. Проведено экспериментальное исследование оценки точности идентификации устройства записи цифровых изображений.

Ключевые слова: изображение, спектральные характеристики, вейвлет-разложение, изолированные особенности.