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The Implementation of Depersonalization Algorithm of Digital Images

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Abstract — The study was conducted and the classification of the signs of digital images was proposed in the article. These signs can uniquely identify the digital devices which the images were created. There was proposed the depersonalizing algorithm of digital images to ensure confidentiality during using of different photo, web cameras and scanners. Practical application of the developed depersonalization algorithm of digital images has shown its effectiveness in protecting equipment from identification by third parties by breaking the direct connection between the digital optoelectronic devices and created digital images.

Keywords — digital images, depersonalization algorithm, digital optoelectronic devices, digital optoelectronic device identification, EXIF data, photo sensor, identification digital images.

I. Introduction

There needs to ensure confidentiality of digital images created by using photo and video cameras in various spheres of human activity.

There exist the various identifying signs of digital optoelectronic devices (DOED) [1]. These signs are depended on their individual characteristics. Besides of this the identification information is saved on the images during all period of post-processing. That is why the photo technical examination of the digital images as usual is performed by two directions [2]: research on digital images and research on photographic materials.

The task of the research is to develop the algorithm of depersonalization of digital images, by removing the identification features of DOED.

II. Identification features of DOED

The development of methods to ensure the author confidentiality of digital images are one of the urgent tasks of information protection.

In most cases the decision on the identification of DOED, used to create the digital image, is taken providing that the digital image under examination is suitable for being identified.

DOED identification data that can be obtained during the examination of the digital images:

setting of shooting conditions;
determination of the image creation time;
restoration of the original image;
the type of DOED used to produce the image;
subsequent digital image processing (in the graphic editors and media converters);
assessment of the changes in the graphic image processing;
the type of the software used for image processing.

General studies for documenting DOED characteristics reflected in the created digital image include frame sizes and EXIF data.

The digital image in JPEG format, the creation algorithm of which is based on the discrete cosine transform (DCT), is applied to the matrix of the original image to produce a new matrix of coefficients (the digital image in a new format) [3]. Therefore, the DCT coefficients of the resulting matrix of the digital image can be attributed to the group features of DOED. They are specific to its model or a series of models [4]. DCT matrix of the digital images and complete information about it are called EXIF data [5]. This data includes additional information (metadata) about the digital image.

In general, the EXIF data include:

name of DOED model;
DOED orientation (vertical / horizontal – for devices with built-in accelerometer);
address of the shooting locations – the position on the earth's surface;
date and time of shooting;
size of the digital image;
digital image resolution;

depth of color in bits;
type of white balance;
focal distance;
equivalent focal distance – the common characteristic of the optical system and the light-sensitive element, which gives information about the viewing angle of the system;
diaphragm;
flash use;
ISO – the sensitivity of DOED;
the sensitivity of the sensor (the matrix), which is set while shooting;
the software, in which the digital image was made (if the image is in JPG format, there will be indicated the DOED software which processed the image; if the image is in RAW format there will be indicated the software which exported it to JPG format, for example, Adobe Photoshop Camera RAW);
exposure time in seconds while the digital image was photographed. It's the interval of time during which the optical system transmits the image to the photosensitive matrix;
exposure time compensation;
information on the right of possession.

In addition, media files can include the following EXIF data: video data; audio data; flash-content (SWF format); Categories – contains information based on Associated Press.

III. Analysis of digital image EXIF data

The analysis of the digital image EXIF data can be carried out using JPEGSnoop software which supports the following image formats: JPG, THM, AVI, DNG, CRW, CR2, NEF, ORF, PEF, RAW, MOV and PDF, Photoshop files [6]. These EXIF data are exported to TXT file. One of the important functions of the JPEGsnoop software is the presence of the internal database that compares the tested digital image with the large number of compression signatures. It's digital signature, with which the resulting digital image is marked during the compression by different algorithms. The digital signature is placed in the noise components of the image. This enables to uniquely determine which DOED was applied to form the digital image. The JPEGsnoop software retrieves the following information from the digital image:

quantization of the matrixes;
the color of sub-sampling;
the quality of JPEG container;
the settings of JPEG container resolution;
Huffman tables. Basing on this table, the coding tree is formed. (The classic Huffman algorithm that receives the frequency table of symbol occurrence in a message. This algorithm is used for compression of textual and graphical information);
Makernotes. Every digital optoelectronic device stores the EXIF information in the extended section. This information is specific to its manufacturer and is contained in the so-called Maker Note section;
RGB histogram – uses all three-color channels and describes the brightness distribution in a single channel and shows the loss in a separate chrominance channel, but it does not show whether the losses are in one or all channels. Color histograms amplify this effect and clearly demonstrate the presence of losses;
markers JPEG (JFIF) – JPEG files contain a sequence of markers. Each of them begins with the 0xFF byte, indicating the beginning of the marker, and with the ID-byte. This JPEG-file structure allows you to quickly find the marker with the necessary data (for example, the length of string, the number of strings and the number of color components of the compressed image);
VLC decoder type (VLC decoding – method of adaptive coding of variable length (VLC) with efficient memory and low complexity for data of various applications, such as coding of digital video data, image data, audio or speech data);
determination of the quality parameters used in Photoshop software;
retrieving of embedded images in Adobe PDF documents.

IV. Individual signs of DOED

The following properties and features for hardware DOED can be defined and used for DOED identification:

1. For digital photo, video, web-cameras:

lens and bayonet mounting system (forms medium steady signs). Bayonet – the kind of connection to fix the optical system (lens) to digital optoelectronic devices. Bayonet is not only mechanical but also electronic interface. It connects microprocessors of the lens and digital optoelectronic device via electrical contacts;
blur – irreversible operation, when the digital image or its parts are redistributed according to some law (forms medium- and high-resistant signs).

*Note***:** The strength of the blur is effected by these physical parameters.

Geometric lens aperture (F): the smaller the number of F, the thinner the depth of the field and the stronger the blur of the foreground and background images.

The focal distance of the lens: the larger the focal length is, the stronger the background image is blurred.

The focus distance to the subject (the distance between the camera and the subject shooted): the smaller the focus distance, the stronger the blur of the background image.

The distance between the subject and the background: the farther the background of the subject, the stronger it is blurred.

Optical scheme: it has a greater effect on the blur type.

The size of light-sensitive matrix module (photosensitive matrix which presents an integrated circuit, consisting of millions of pixel cells (photodiodes): photodiodes are able to convert light energy into electric charge stream. It can be read and amplified by an analog-digital convertor and is converted into a predetermined bit binary code. Then this code goes to the digital processor of the optoelectronic device for subsequent processing). The larger the size is, the larger the angle of the view is and the closer you need to come to the subject.

Therefore, full-format DOEU blurs the background image more strongly.

Special nozzles and filters on the lens.

The photo sensor: it forms stable attributes at all frequencies.

2. For digital scanners:

inhomogeneity of light-sensitive elements of the scanner line;
deviation of the scanner carriage movement from linearity;
uneven illumination and uneven pressing to the glass of scanned original, etc;
in addition to DOED features mentioned above, their individual features are largely determined by the applicable built-processing algorithms of the created digital images:

1. Image reconstruction algorithms from a mosaic photo sensor structure – is based on measuring only one color component at each point of photo sensor, and the missing components are calculated basing on the neighboring data points. This technology creates a photo sensor which measures three colors at each pixel simultaneously.

2. Improving of the contour sharpness (the algorithm reproduces the traditional technique of the film mask. This mask is used to increase the sharpness of edges in the image. The algorithm corrects blurring of the digital image that appears in the result of scanning, printing or interpolation) and noise reduction (the algorithm of suppression of all detected noises which have been generated in the digital image before its being recorded).

The post-processing algorithms of creating digital images by the digital photo, video and web-cameras can be both disengaged and engaged.

*In digital scanners***,** a resulting image can pass two-level process – in the scanner itself with the help of calibration curves, the suppression of dust on the scanned copy and scanner glass, and at the driver level, where the subjective improvement of the quality of the digital image is carried out.

Each DOED (regardless of the format produced by the digital image) has its own frequency-contrast characteristic, which is type of amplitude-frequency characteristic (AFC) of the optical system and a photosensor. The amplitude-frequency characteristic is not constant in different parts of the digital image, and its correct comparison is best carried out by the pictures of the radial test-object (the test-object is used for the quantitative determination of the resolution and for the modulation transfer of the lens and supersensitive matrix), but it is not always feasible on practice. Therefore, to the individual features of DOED can belong its pattern of the photo-response non-uniformity; the presence and location of contamination on its photo sensor (photo matrix), which is transferable to the digital image (Fig. 1). This feature is inherent to the mirror type of DOED, as, while replacing the lens, the photo sensor inevitably gets covered in dust.

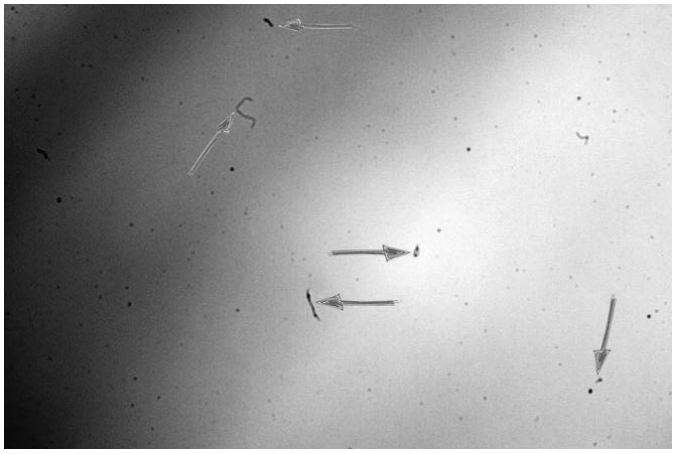

Fig. 1. The presence of impurities on the matrix of the photosensor DOED (arrows indicate the presence of dust impregnations).

In addition, there are cases when the surface of the optical system in the non-separable photo, video, web-cameras and scanners is contaminated (Fig. 2).

Fig. 2. Characteristic surface contamination of the optical system.

The use of visible and invisible digital watermark is a common method of protection against unauthorized copying of digital content. This also makes it possible to uniquely identify the DOED in the digital image that it creates (Fig. 3) [7].

Implementation of the digital watermark is carried out by using the following criteria:

digital watermark is introduced into the digital image by the special algorithm, which does not allow to determine the presence of the digital watermark in the image;
the presence of the secret key;
the possibility of proving the existence of a digital watermark to a third party without disclosing the secret key;
digital watermark maintains all types of image distortions or the maximum possible number of images, except for those that make it practically useless for use;

the developed digital watermark models are resistant to any changes in the digital image.

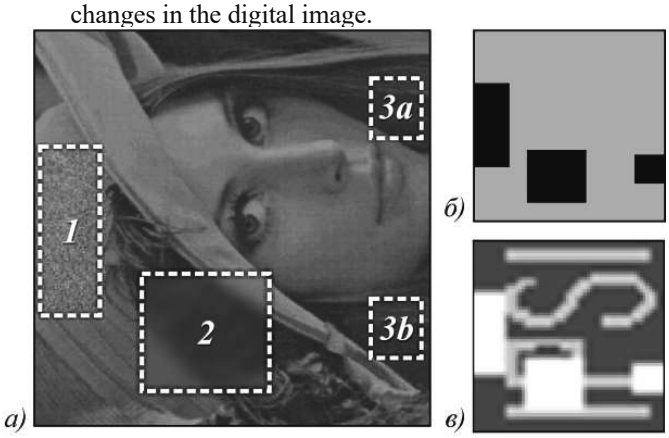

Fig. 3. The results of detecting and extracting the digital watermark from the modified image: a) the map of the detected modified blocks (1,2,3a, 3b); b) the modified blocks (marked in black); c) the extracted digital watermark (white color - damaged blocks, and light gray – restored digital watermark – IPSI symbols).

V. Identification of DOED by the digital noise

Digital noise is a defect of the digital image, made by the DOED photo sensor. The digital noise shows itself in the form of randomly spaced points of different brightness and color. It is especially noticeable on plain surfaces – the sky, the skin, and the shadow areas. The digital noise gives the digital image unnatural appearance – it seems to be "sprinkled" with sand [8]. The digital noise is typical of each matrix of the optoelectronic digital device. It becomes clearly visible when increasing the sensitivity (ISO 400, 800, 1600, etc.).

The digital noise is usually associated with an electrical error of the photo sensor (matrix). This phenomenon arises from the individualities of the refraction of light – there appear defective multi-colored pixels on the matrix. The more pixels are located on the matrix, the smaller their size is. Increasing the amount of the pixels on the matrix results in increasing of their sensitivity. It stimulates the noise increase. It should also be noted that while increasing the sensitivity (ISO), the temperature of the photo sensor becomes also increased, which contributes to the developing of the noise. The noise level depends on the technical characteristics of the photo sensor and the duration (time) of the exposure. The digital noise is divided into: permanent, incidental, luminance and chrominance.

Permanent digital noise equally appears on all digital images created by DOED and is connected with the presence of "hot" and "broken" pixels of its photo sensor. Hot pixels – occur in the form of colored pixels and depend on the photo sensor temperature. During the work of the matrix the temperature of pixels rises and the pixels, unsustainable to high temperature, start to "act up" giving the signal which at times may be different from normal neighboring pixels and to be brighter or darker than you need. Hot pixels are usually red, blue or green. Broken pixels – appear regardless of the shooting mode and may be bright or very dark, depending on the mode they lost their efficiency in. If the broken pixel "floats" in the switched-on state, there will be bright pixels (usually white), because it takes too much light. If the pixel "floats" in the off position, then the pixel will be dark (almost black), because it is very poorly reactive to light. In the place of the "broken" pixels there are always bright or dark spots. "Hot" pixels appear as colored dots, positioned at the same place from frame to frame during long exposures when the photo sensor is extremely hot. For identification of the "hot" pixels it is necessary to cover DOED with dustproof camera lens cap, to select the maximum ISO sensitivity value, set the shutter speed of 30 seconds, turn off the built-in noise reduction (if any) and make some control of digital images. Their visual analysis shows the presence or absence of "hot" pixels.

Luminance digital noise is shown on the image in the form of small dark spots (or points) and resembles a *film grain*. Film grain – grain size of the image is increased due to the process of increasing the film sensitivity. Large grains reduce the resolution of the film.

Chrominance noise is shown on the image in the form of small spots (points) of a different color, different from the color of the areas where this noise is shown (that is why it is clearly visible). Chrominance digital noise is striking and unpleasant for viewing.

VI. Depersonalization algorithm of digital images

Depersonalization of the digital image means absence of identifying features that can help to uniquely identify DOED. The sequence of actions is proposed and carried out by the authors for the depersonalization of the digital image. It is presented in the form of the algorithm in Fig. 4.

Creating a digital image with the lowest possible level of digital noise

Among recommendations to reduce primary noise generated in the digital image there are conventional steps to reduce internal noise of the photo sensor, namely [9]:

- decreasing of the ISO sensitivity;
- reducing of exposure;
- use of a high aperture lens (if the aperture is opened wider, the exposure will be less);
- shooting under a bright light (or using the flash);

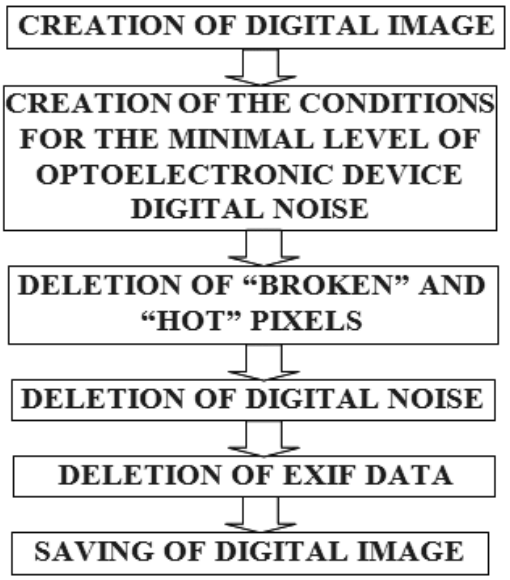

Fig. 4. Depersonalization algorithm of digital images.

- using a built-in noise suppression function;
- avoiding too long operating of DOED without its being off (it causes heating of the photo sensor, especially of mirror cameras in the focus mode of LCD display);
- saving of digital images in RAW format. This is the format of the digital image containing the raw data received from the photo sensor. Complete information about the stored information signal is contained in such files. This information has no precise specifications (standard). It is also sometimes referred to as "raw" format.

The implementation of specialized software is carried out in the proposed algorithm of depersonalization of the digital images following the next steps.

Removing of "broken" and "hot" pixels

If DOED creates the digital image in RAW format, the task of removing the "broken" and "hot" pixels is greatly simplified by using specialized software – Hot Pixel Eliminator (the software can distinguish between "hot" and "broken" pixels from the bright glare and light sources) [10], Pixel Fixer (the software can automatically remove hot and broken pixels from the raw digital images) [11].

Note: If the specialized software is not able to remove the "broken" and "hot" pixels, or if the generated digital image is saved in the JPEG-format, you can remove them manually in Adobe Photoshop graphics editor by using Patch Tool.

Removing of digital noise

Universal algorithms of removing/suppressing the digital noise have not been yet developed. The specialized software, that implements these algorithms, cannot always distinguish fine details of the digital image from the digital noise. Consequently, strong suppression of the digital noise often leads to the partial loss of little bits and is shown in the form of digital image blur. The specialized software used for the removal / suppression of the digital noise is to consider the following factors:

- the model of DOED;
- causes for the photo sensor digital noise;
- the presence of little bits on the digital image.

The specialized software should be able to manually set the modes of disposal / suppression of the digital noise, as the perception of digital images by the human eye is subjective. The practical use of this software shows that, with the user's appropriate experience skills, better results can be achieved in manual mode than in automatic one. The general recommendations of the specialized software applications should include the implementation of the procedure of the noise deletion / suppression before other operations such as color correction, brightness / contrast, resize, etc. There are a lot of specialized commercial software that can be used to suppress the digital noise, such as Adobe Camera RAW, Adobe Light Room and others. The specialized commercial software Movavi Photo Denoise was used by the authors to test the removal operation of the digital noise (Fig. 5) [12].

a)

b)

Fig. 5. The result of the practical implementation defects removal and photosensor digital noise correction: a) the existence of "broken" pixel in digital image; b) correction photosensor digital noise in digital image.

VII. Removing of EXIF data

Removing of EXIF data helps to depersonalize DOED according to its inserted metadata into the digital image during its creation, and to hide information about specific software that the digital image has been processed by [5].

All the specialized software used to perform operations with the EXIF data can be divided into three groups, each consisting of specific function set:

metadata reviewing;

selected metadata tags editing;

complete removing of metadata.

It should be noted that the operation of removing the EXIF data is implemented by the same principle as editing. The most effective universal means for this operation is ExifTool software. This tool is available for all platforms and recognizes additional tags (EXIF chunks) of the most DOED and software used for post-processing of the digital images [13].

Acknowledgment

The algorithm of depersonalization of digital images was developed during researching of various characteristics. These characteristics uniquely identify of DOED.

The practical usage of the developed algorithm allows to depersonalize of the digital image by removing the identification features of DOED.

The algorithm can be useful for those who perform their professional duties for information security and others for personal security.

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