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Validation through a binary key code and a polarization sensitive digital technique

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Abstract

We implement a validation technique, using a polarization-encoding architecture based on digital speckle correlation and a binary key code. A validation mark is thus generated which can be affixed on a document or included on an optical chip or magnetic tape in any card. Security is duplicated by the speckle and polarization characteristics of the procedure. Both encoded mark and decoding binary key are stored digitally. The original input can be retrieved for authentication by a subtraction operation performed with conventional software. No additional experimental setups are required in the decoding step. Experimental results are presented to demonstrate the method.

Keywords: Digital speckle correlation; Optical data processing; Information processing

1. Introduction

We entered in an increasing technical competition of optical processing methods for information validity applications [1–6]. Optics shows devices with the property that data can be stored or retrieved in parallel and at high speed.

Among recent methods for security we can mention optical correlators and random phase encoding [2]. These optical correlators represent an interesting tool for validation purposes, but they have to be simplified, making them more cost-effective and experimentally available at the respective authentication stations. Recently, a digital holographic technique that uses a CCD camera for direct recording of a hologram has been combined with random phase encoding [7]. This method shows the great potential this combination represents. Besides the many degrees of freedom digital processing provides it is well suited to store real images and information.

Digital interferometers can then also be adopted. The digital speckle pattern correlators [8,9], widely used in metrology applications, can be adapted to validation purposes. The technique combines holographic and speckle interferometry having an image-plane hologram setup, following

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the methods of double exposure holography, and based on the digital correlation of speckle patterns. Digital speckle correlators are also catalogued as polarization sensitive interferometers [10]. A basic application is found in the technique for encoding optical logic operations thanks to the polarization preserving property of these correlators [11].

In this context, we are oriented to use the digital speckle correlator architecture, together with a binary key code [12] to generate a validation mark, to provide a new alternative for an encoding security system We call this composite mark the polarization-encoded mark. This represents an additional degree of freedom in securing the information by combining polarization with a binary key code. It cannot be detected from the normal gray scale using an intensity-sensitive device such as a CCD camera. Main advantages of this approach are that no energy is lost and it requires no filtering or transformations. Also the requirements of intensity equalization and critical alignment are eliminated. We stress the fact that we do not bond the whole image or document to the mark. It is simply affixed in one portion, a corner for instance. So there are no restrictions to the image or document to be gray-scaled or not. Moreover, there is no need for using additional polarization arrays, making this approach simpler to realize. This is a main difference with other previously existing proposals that also use polarization encoding [13]. Once the client receives the polarization-encoded mark, by comparing through a subtraction operation with the reference polarization-speckled decoding key, validation is accomplished. When the decoding key matches the encoded mark, the original signal can be assumed as valid. If there is a difference, it can be either a mismatch with the expected mark or the correlation is diminished by showing a general visibility reduction. Thus we can verify the authenticity in terms of the visibility, besides matching the original expected mark.

The interferometer is only used in the encoding process, as decoding can be simply accomplished in any PC by a subtraction operation, overcoming the use of similar experimental setups for information retrieval. In this proposal we are taking advantage not only for needing the key code but also the polarization direction of the original illuminating laser beam as a second alternative to validate the transmitted information. Speckle acts as additive noise, only modifying the pixel value but not its relative position.

2. Experimental procedure

Fig. 1 shows the experimental basic configuration to encode the mark. Both beams of the interferometer are made to coincide in their polarization directions and are brought together to illuminate the diffusing surface S. This is equivalent to obtaining two different speckle patterns from the same surface, one that serves as a reference wave, and the other as an object wave. This interference procedure allows the generation of a phase mask. The CCD camera stores these patterns in a host computer. After processing, the resulting pattern is attached or bonded to the primary document or image. The binary input A, which has to be recognized to validate the information, is made such that introduces no local changes in the polarization direction in the beam. It should be introduced in the indicated position. Input B represents the binary key code with similar

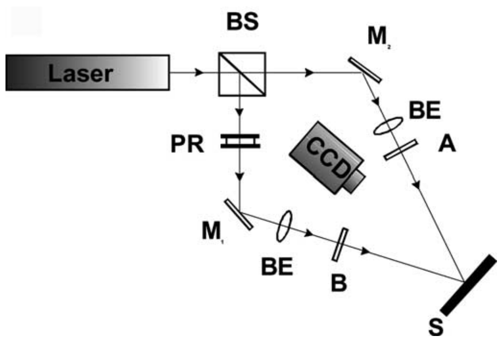

Fig. 1. Experimental setup to generate the encoded mark: a linearly polarized laser source is divided in two by a beamsplitter BS. In each arm is shown the position where the binary marks (A) and (B) are inserted according to the procedure described in the text. PR is a polarization rotator, $M_{1,2}$ are mirrors, BE are beam-expanders and S is a speckle generating surface (diffuser).

characteristics as A, and should be positioned in the indicated path.

We accomplish the operation by inserting the input A in one path, with no coding key B in the other one. After storing the resulting image in the frame grabber of the computer, we insert key code B in the empty path and taking out object A. This image is also stored, and then subtracted from the first one. Speckle correlation is performed by subtraction. The result is the encoded mark.

The image with key code B alone can be sent to all possible clients who need to validate the information. Once they receive the mark to be decoded, they simply perform the pixel-to-pixel subtraction to retrieve the desired data. We call this composite mark to be decoded the polarization-encoded mark. An example of this method is schemed in Fig. 2. Clearly, the restored input object coincides in every single detail with the original.

The success in obtaining the pertaining input A strongly depends on the zero value in the dark areas of the original object. This represents no constrain as by image processing we can assure to accomplish this binarization feature. That is, forcing dark areas provides a higher discrimination capability.

3. Polarization encoding

Let us assume linearly polarized laser light. In any general situation, for example in a metrology test with digital techniques, we note that after

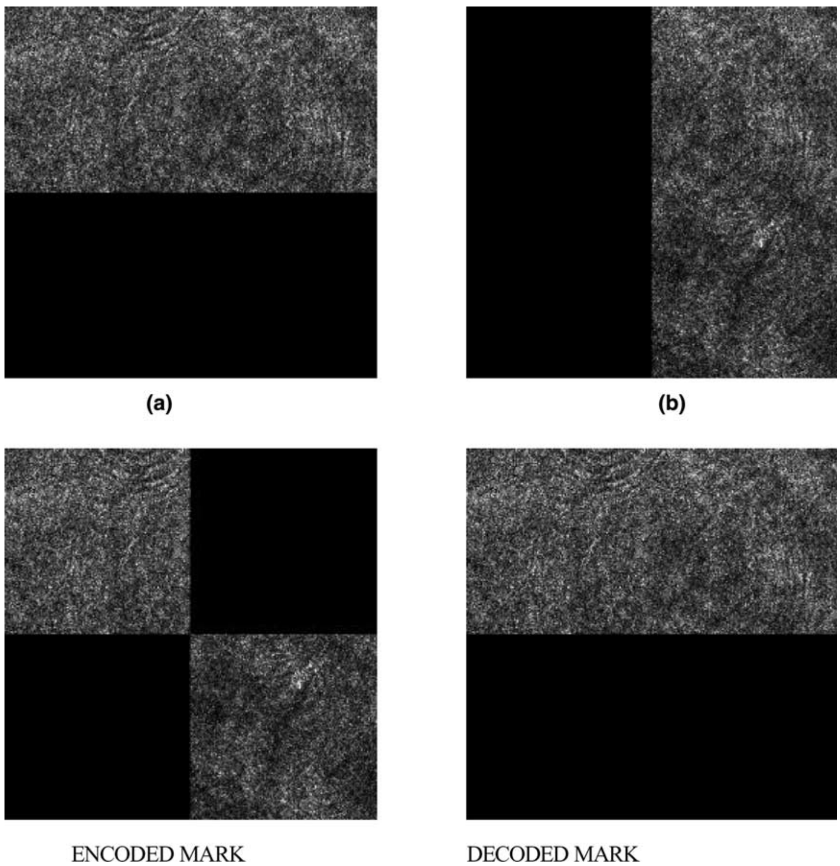

Fig. 2. Validation procedure description. The sequence shows both input object A and key code B, along with the resulting coded mark after subtraction operation. Finally, the restored input object after the decoding step.

performing the usual subtraction and observing this operation in real time, any phase change between frames introduces a set of correlation fringes. Besides, if a rotation is induced in the polarization direction in one path of the interferometer a decrease in the general visibility of the resulting fringes can be observed.

Denoting the intensity distribution in the TV monitor that arises from a pixel-to-pixel subtraction by $I(x,y)$, and assuming no phase disturbances between both reference and actual frames, then [11]

$$I(x,y) = |4|C|^2 \sin^2 \Delta\theta \cos\varphi(x,y)|, \quad (1)$$

where C is the complex amplitude, which is assumed to be constant and equal in both optical paths, $\varphi(x,y)$ represents the phase of the resulting speckle pattern in the (x,y) pixel location, and $\Delta\theta$ is the variation of the angle formed by the polarization direction in the stored reference frame with respect to the actual frames. When the direction coincides ($\Delta\theta = 0°$ or $180°$) the TV screen is black, if not it is white with a speckled background ($\Delta\theta = 90°$ or $270°$) or exhibits a speckled gray level. We turned the polarization encoding into an intensity display on the TV monitor. It has to be stressed that each stored frame preserves the information on the polarization. The subtraction operation reveals the difference in the polarization direction, if any, between those frames. We emphasize that B is a binary space mask, and does not alter this polarization-encoding procedure.

The underlying advantage of this procedure is the presence of the speckle pattern in the key code, as it is almost impossible to duplicate.

If the encoded mark is made with a different polarization direction than that stored in the original key code B, a contrast lost is readily seen. Fig. 3 shows several cases of restored marks where, while making the coded mark, the polarization direction has been rotated with respect to that originally stored in B. Through the corresponding intensity histograms we easily detect the different gray levels content with respect to the non-rotated case. Each histogram was taken along the same horizontal line in a speckled area of the image. When polarization direction matches in both the key code B and the polarization-encoded mark, then the higher speckle pattern visibility is

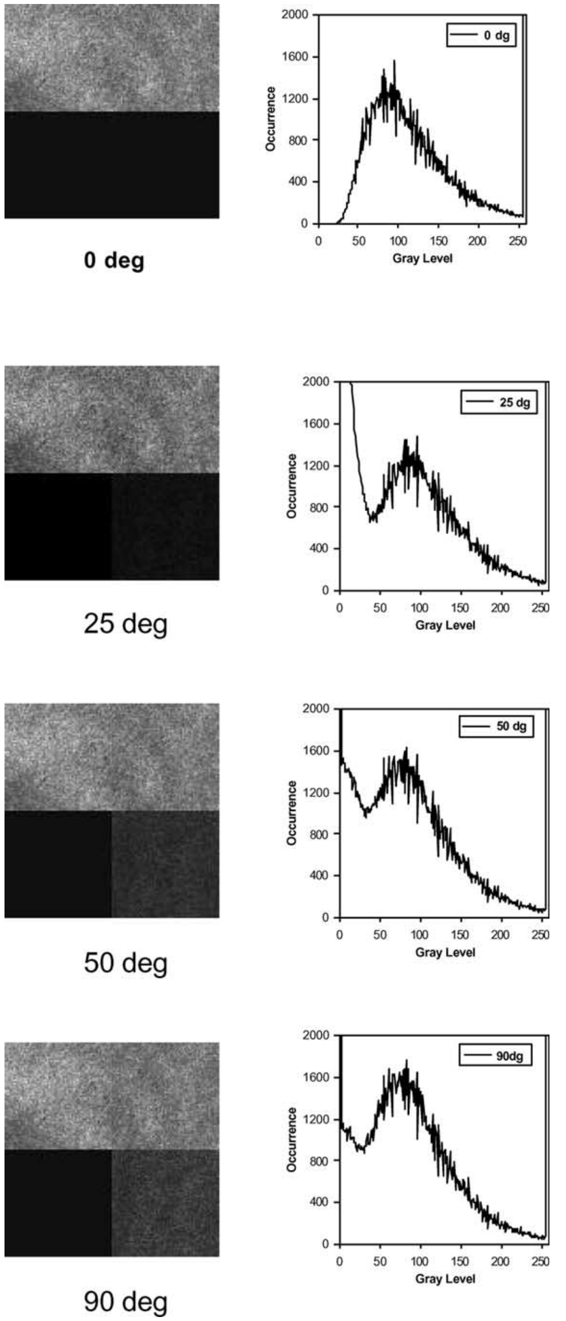

Fig. 3. We compared the reconstructed input object A for the cases where the polarization has been rotated with respect to that originally stored in the key code. In every case we rotated the polarization direction in the path of key code B, but the same is valid for the path of input A. Intensity histograms for each example are shown to display the differences in gray levels content in the whole image.

achieved. For the 0° case, there is the highest quantity of zero intensity levels. This amount diminishes as the angle between the two images increases. From the plots we can distinguish the increment of gray levels ranging fom 50 to 100, with a greater population between 0 and 50. This behavior shows what has to be expected when no matching is found.

The polarization-encoded mark cannot be detected from the normal gray-scaled mark using an intensity-sensitive device as a CCD camera.

Even when the key code could be intercepted, the polarization direction remains as a second validation key. Several key codes with different stored polarization can be alternatively employed according to a predetermined sequence to avoid counterfeiting.

Regarding the influence of the speckle carrier, Fig. 4 shows the case where the coded mark is made with another speckle pattern than the original. The upper right coded mark is made with a speckle pattern different from that of the key code

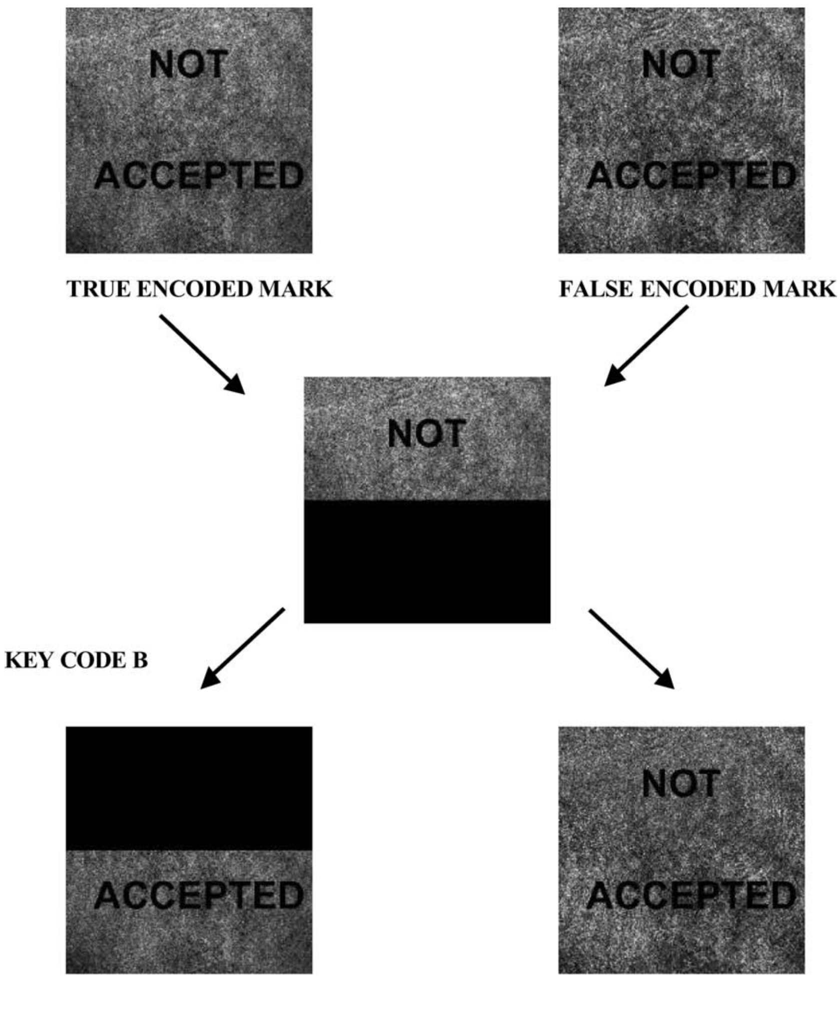

Fig. 4. Comparison between the legitimate validation of input A (upper left) and the case where another speckle pattern has been used in the coding operation (upper right). After decoding with key code B (center), we are readily able to detect true from false marks.

(center image). The differences in the respective decoded marks are readily seen.

A spatial light modulator can generate more complex binary key codes for example.

4. Conclusions

Coded input can be magnetically affixed to a corner of an image, or included in a card chip, to verify authenticity. This can also be bonded to another primary document, such as a fingerprint or a picture of a person. It has to be emphasized that this code do not mask the whole document, but it is simply tagged to it. So there are no restrictions to use gray scales images as with other existing proposals.

It is clear that no position matching is needed, as the frames are read in a format that needs only to be captured by usual software (not by an imaging device), which performs the subtraction with no further instructions.

In conclusion, we have shown a validation technique that uses digital correlation of speckle patterns together with a binary key code and one of its main advantages, it sensitivity to polarization rotations to be used as a possible secondary key code. This technique allows the encoded marks to be stored, transmitted, and decoded digitally. Other principal features over standard procedures are the simplicity, being independent of diffraction efficiencies, requires no transformations or filtering and there is no need for laboratory equipment in the decoding step. In our case the signal-to-noise ratio is given in terms of the visibility of the resulting decoded output.

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