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Specificity of correlation pattern recognition methods application in security holograms identity control apparatus

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Abstract

Automatic inspection of security hologram (SH) identity is highly demanded issue due high distribution of SH worldwide to protect documents such as passports, driving licenses, banknotes etc. While most of the known approaches use inspection of SH design features none of these approaches inspect the features of its surface relief that is a direct contribution to original master matrix used for these holograms production. In our previous works we represented the device that was developed to provide SH identification by processing of coherent responses of its surface elements. Most of the algorithms used in this device are based on application of correlation pattern recognition methods. The main issue of the present article is a description of these methods application specificities.

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1. Introduction

Application of special holographic marks, also known as security holograms (SH) or optical variable devices (OVD), is one of the widespread methods to provide high level of security of valuable papers and documents in Russian Federation and worldwide. High distribution of SH is supported by its application to secure such a documents as ID cards, passports, driving licenses, credit cards, and banknotes etc. This statement raises high interests in development of automatic devices of identity control of SH.

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High production difficulty of master-matrix, that is used for stamping the SH complex diffractive surface structures, causes the holograms produced by this matrix to be highly unique elements. Thus the operative verification whether the chosen SH were produced by its original master-matrix or not can be very important procedure for counterstand the falsification of SH. One of the methods to provide such a procedure can be based on observation of SH diffractive structure local specificities.

In our previous publications we introduced the Optical-Electronic Scanner (OES) that was developed for automatic inspection of local SH specificities by numeric analysis of coherent diffraction responses of small surface elements [Zlokazov et. al. (2013), Zlokazov et.al. (2014)]. Capturing the diffracted light intensity by matrix photodetector and comparing the captured image responses with the same sample of the same local element of template SH in different points allows to obtain originality of the hologram under investigation. Specific problem of this approach is the requirement of precise positioning of control laser beam head to provide image matching with low error rate. Two ways were realized to decrease the affect of positioning error: 1) realisation of control head positioning in connection to SH global design and 2) application of the knowledge about possible distortions and variability in template image data that will be used in digital processing of surface diffraction responses captured by coherent control system of OES. In first case the aiming channel were developed to recognise SH design images and to provide the shift of optical head in front of the desired element of SH. In second case, using coherent control channel, we gathered data from different training examples of template SH with different shift error of optical head positioning. In both cases application of image processing methods based on invariant pattern recognition algorithms allowed to realize the SH identity procedure in OES with high precision.

2. Image recognition using distortion invariant correlation methods

Correlation pattern recognition (CPR) is widely used technique in digital image processing. In the basis of these methods lies the calculation and analysis of correlation dependence between input data and template object functions. Advantage of CPR methods application is high precision in positioning of target object on image field and possibility of stable target recognition in presence of distortions due to application of distortion-invariant composite correlation filters (CCF) [Kumar (1992)]. CCF is a digitally synthesized two-dimensional data massive which elements can be complex or real values. The CCF calculation algorithms imply the application of training images set which represent the template object under different distortions determined a priori. One of the most investigated and efficiently applied CCF are filters with optimization of output correlation field parameters which are mathematically efficient and showed promising recognition capabilities of objects represented by grayscale images [Zlokazov et.al. (2012)].

![Fig. 1. block-scheme of distortion invariant correlation image recognition method implementation based on CCF.](image-url)
Figure 1 represents the input image correlation recognition algorithm using CCF. Training images captured by data acquisition system during the preliminary adjustment process of OES image recognition unit are subjected to preprocessing in order to suppress the undesired noises and emphasize the characteristic features of template object in different possible variations of representation. Further the preprocessed training images are sent to CCF synthesis unit that stores the synthesized CCF in OES memory. Also the process of threshold determination (not shown on figure 1) is required for each synthesized CCF on the preliminary adjustment step. This process includes the statistical investigation of CCF response on input images of true and false target objects under different variations determined a priori. The same image-preprocessing unit must be used for processing of input images during the OES performance in operational regime. The acquired and preprocessed input images are sent to correlation processing unit “xcorr”. The output distribution of correlation function amplitude is subjected to thresholding operation that searches peaks and compares its values with threshold value calculated on preliminary adjustment step. If the value of correlation peak exceeds threshold value the decision is “true” and input object is classified as target object. If correlation peak value is less than threshold value the input object is classified as false.

3. Aiming Channel

Most of the real SH’s that used in our researches during OES development have deviation of optical head position relative to secured document body content such as printed text, images, and other security elements. Thus the positioning of control head in front of the hologram element to be investigated must be made independently from position of document “non holographic” elements. For this case an aiming channel was mounded to provide the recognition of SH design images.

Figure 2 represents the optical scheme of aiming channel. Several LED-sources were used to eliminate the SH surface in order to reconstruct the encrypted images and project these images on array of photo-detectors (PDA). Providing a document scan by aiming channel head allows to achieve the SH design images from several angular positions light sources. Merging of all the achieved images allowed the detailed visualization the SH design elements. Nevertheless the reference elements of SH design that was chosen to provide the mapping control appeared roughly imaged in most cases (see figure 2(b)).

Application of correlation pattern recognition methods gave the decision of chosen SH design reference elements rough images recognition problem. We used computer models of reference elements subjected to distortion similar to those, which were observed during the capturing and merging of different template examples. Developed algorithm allowed to obtain the positioning precision of optical head to be about 1mm.

![Diagram](image_url)

Fig 2: a) Aiming channel optical scheme; b) example of the image processed and merged in aiming channel, three different reference elements were recognized using distortion invariant pattern recognition methods.
4. Coherent control channel

The local structure of SH is represented by diffraction grating patterns with sizes from 2 to 200um, periods in the range from 0.4 to 2.0um and different orientations. Illumination of such a patterns by coherent light provides appearance of characteristic diffraction peaks in scattered light intensity distribution that can be captured by matrix photo-detector. Elements with different set of gratings will produce diffraction images with different spatial distribution of diffraction peaks. To capture such an images an optical scheme represented on figure 3 can be used in coherent control head construction.

The scheme uses laser module contained by four laser diodes: blue, green, red, and infrared. Flexible fiber-optical light guides were used to deliver an illumination from all the lasers to optical head. The opened ends of optical fibers were mounted on visualising disc such that to provide the normal illumination of SH surface. Such a construction allowed to visualise a 1st diffraction orders on a top surface of visualizer and capture of these bright points by photo detector array (PDA) while DC order was reflected back to visualizer and attenuated by fiber ends mounting. The collimating objective refracts the emitted laser light such that the +/- 1st diffraction orders appear focused on lower surface of visualizer.

As the sizes of SH surface grating patterns are less than precision of optical head positioning error, two ways of solving this problem were developed. The first one was the size of the laser spot on SH surface was set up to be about 0.5mm and the second one was the application of CCF implementation concept in training of the control channel image recognition algorithms [Kumar (1992)]. For every chosen cell of SH surface with the size 0.5x0.5mm the set of training images was contained by the diffraction images of cell itself also the images of neighbour cells were added. This allowed to compensate the lack of precision of aiming channel positioning and increase the stability of OES performance in presence of local stretches of SH surface. In order to increase the stability of recognition algorithms in presence of possible imperfections of template examples of chosen SH, several SH examples must be used to gather the training data. Thus the set of training spectral images for each SH surface zone included the spectral images of zone itself, spectral images of neighbour zones taken from several template examples of chosen SH type.

Application of CCF implementation methods in image processing algorithms allowed to obtain the mean discrimination error to be less than 5%, in some cases it was less than 1%.

Fig. 3: a) Coherent control channel optical scheme; b) image of SH small surface element coherent diffraction response captured by OES control channel camera.
5. Conclusion

Represented article illustrated the examples of efficient implementation of distortion-invariant composite correlation filters in optical-electronic scanner of security holograms surface. Two OES basic units performance is based on recognition of images captured by its own image acquisition cameras. CCF application in Aiming Channel processing algorithms allowed to provide the mapping of Control Head using rough images of SH design elements with 1mm precision. Implementation of CCF methods for Control Head shift-invariant processing of surface local elements coherent diffraction responses allowed to provide the identification of holograms with about 0.5-5% of error probability.

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References