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Improved integral imaging based image copyright protection algorithm using 3-D computational integral imaging pickup and super-resolution reconstruction technique

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ABSTRACT

Cellular automata transform (CAT) based watermarking method can provide multi-transform planes for embedding watermark. In this paper, to overcome conventional transform-based watermarking methods have only one transform plane for watermark embedding, we propose a CAT-based watermarking system, in which the three-dimensional (3-D) watermark data is decomposed by the computational integral imaging (CII) technique and be embedded into the CAT domain. However, in the 3-D watermark reconstruction process, the computational integral imaging reconstruction (CIIR) technique in CII system that can degrade the quality of the extracted watermark due to the pixel overlapping. We introduce the super-resolution reconstruction technique that can effectively improve this problem. Some experiments are carried out to verify the performance of the CAT-based watermarking scheme. From the experimental results, the proposed watermarking system can provide good imperceptibility and high robustness.

1. Introduction

Digital multimedia transmissions over the Internet have made substantial process in the last few years. This fast development induces a great demand for intellectual property right protection of digital information like images, texts, audios and videos. The most well-known technique for protecting the copyright of images is called digital watermarking. A typical digital watermarking is to identify the ownership of multimedia object or content by embedding the watermark into it. Several watermarking methods for digital images have been proposed in recent years [1–4]. These methods can be classified into two types: embedding the watermark into the spatial domain, and embedding the watermark into the frequency domain. The first type provides a better computing performance but usually degraded robustness, while the second is more robust, especially when the watermarked image is compressed with the JPEG compression methods.

For image, audio and video compression algorithms, transform coding is one of the most important building blocks for processing with the input multimedia. Therefore, watermarking based transform domain is mostly encountered in the literature. Among the practical schemes, discrete Fourier transform (DFT), discrete cosine transform (DCT), and discrete wavelet transform (DWT) are most popular transform coding schemes for academic researchers and practical implementations.

However, most of the above methods have their drawbacks. Since these methods have only one transform plane for watermarks embedding, so the embedded watermark data can be removed easily. In order to increase the flexibility in data hiding, in recent years, the digital image watermarking based cellular automata transform (CAT) as an interesting topic has been proposed [5,6].

One advantage of the CAT-based digital image watermarking is that the watermark information can embed different transform planes according to the cellular automata (CA) basis functions. This property provides higher security than the conventional transform-based methods. In addition, CAT as an orthogonal transform which offers considerable simplicity in the calculation of the transform coefficient, in other words, it can improve the quality of the watermarked image by reducing energy loss compared with the conventional complicated transform process.

Recently, to improve the robustness of watermarks, the three-dimensional (3-D) watermark based digital image watermarking techniques have been proposed [7,8]. In those methods a picked-up elemental image array (EIA) was embedded into the middle frequencies of DWT [7] or CAT [8], because the EIA is composed of a number of small elemental images having their own perspectives of a 3-D image, this property of the EIA watermark can make a

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robust reconstruction of the watermark image available even though there are some data losses in the embedded watermark by attacks. In the watermarking reconstruction process, the computational integral imaging reconstruction (CIIR) technique [7–9] was used. The CIIR-based method has greatly improved the robustness compared with the conventional two-dimensional (2-D) watermark based watermarking technique. However, in the reconstruction process, the CIIR algorithm is a pixel overlapping method, the interference of adjacent pixels will degrade the quality of the reconstructed watermark.

In this paper, we propose an algorithm that the CIIR technique replaced by the super-resolution reconstruction algorithm and CAT-based watermarking scheme to minimize the drawbacks of previous algorithms. In the watermark embedding process, a 3-D watermark is picked-up and captured by a CCD camera in the form of the EIA. The captured EIA is embedded into the middle frequency of CAT. In the watermark extracting process, the 3-D watermark is reconstructed by the super-resolution reconstruction algorithm. Compared with conventional transform-based image watermarking algorithms, the proposed scheme can provide multi-frequency domains for embedding watermark. In other words, this proposed digital watermarking system provides high security. In addition, the 3-D watermark based watermarking system increase the robustness of the watermark because of the property of 3-D data redundancy.

2. Review of CIIR

The CIIR algorithm produces only one view at a time. The operational principle of the CIIR algorithm is schematically described in Fig. 1. The CIIR algorithm is a computational reconstruction technique can computationally reconstruct the 3D object image by mapping elemental images inversely through a virtual pinhole array based on the ray optics [10–13]. In this method, each elemental image of the captured EIA is inversely mapped onto the reconstructed image plane through each corresponding pinhole with a magnification factor of $M = l/g$, in which l and g represent the distance between the reconstructed image plane (l) to the virtual pinhole array ($z=0$) and the distance between the EIA (g) to the virtual pinhole array ($z=0$), respectively.

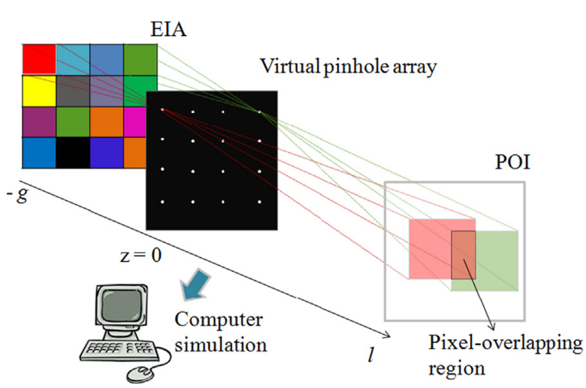

Fig. 1. The operational principle of CIIR algorithm.

A set of discrete plane object images (POIs) can be reconstructed along the output plane, the enlarged elemental image is overlapped and summed at the corresponding pixels of the reconstructed image plane. To completely reconstruct a plane image of a 3D image at the distance of $z=l$, the same process must be repeatedly performed to all of the picked-up elemental images through each corresponding pinhole. Basically this CIIR method can reconstruct the object image as a form of depth-dependent POIs along the output plane. However, in this method, not only the clearly focused target POI but also the defocused POIs are concurrently reconstructed on each output plane, thereby the quality of the reconstructed target images will be decreased. Meanwhile, the CIIR will degrade the resolution of reconstructed image, because of the magnification for each inversely mapped elemental image, as shown in Fig. 1, the superposition occurs for the magnification factor. And the overlapping numbers of inversely mapped elemental images result in pixels aliasing. These variations in intensity generate the degradation of the quality of the reconstructed images.

3. The proposed method

In this paper, a new digital image watermarking technique for copyright protection is proposed by using a 3-D watermark, combining the integral imaging pickup and super-resolution in CII system. This proposed scheme can solve the weak point having only one transform reference in DCT, DFT and DWT domains watermarking methods. Meanwhile, the system using super-resolution reconstruction technique can remedy the shortcomings of the CIIR technique. This proposed watermarking system basically comprises three processes: 3-D watermark pickup, watermark embedding, and watermark reconstruction, as shown in Fig. 2.

3.1. 3-D watermark pickup

The computational integral imaging (CII) [14] system is shown in Fig. 3, which composes of two parts. The first part is the pickup process of the 3-D watermark, and the second part is the CIIR using the picked-up EIA. In the pickup process of CII as shown Fig. 3(a), the EIA is recorded using a lenslet array and an image sensor (CCD camera). On the other hand, the CIIR process provides a series of POIs within a specific depth range by reconstructing POIs at any arbitrary distance from the lenslet array, as shown in Fig. 3(b).

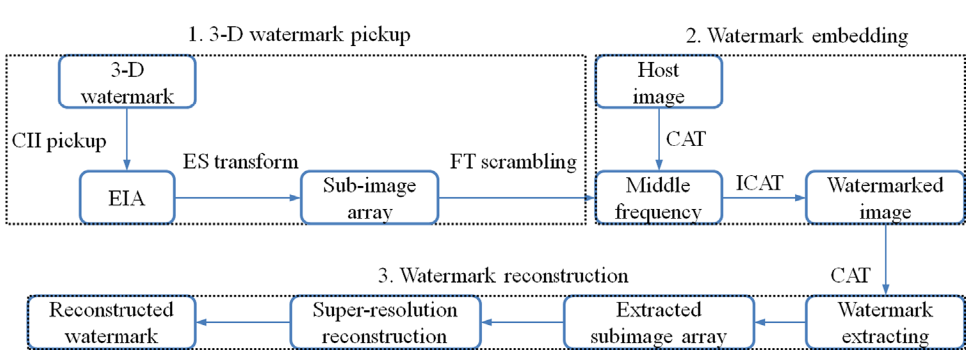

Fig. 2. A System structure of the proposed watermarking algorithm.