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厦门大学

博 士 学 位 论 文

计算全息在数字水印中的应用研究

Research and Application of Computer Generated Hologram on Digital Watermarking

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摘要

随着多媒体技术和网络技术的发展，数字多媒体产品的版权保护和安全问题成为一个相当重要而又富有挑战性的研究课题。作为一种数字产品版权保护的有效解决方案，数字水印技术被广泛地研究。由于全息图具有天然的加密特性以及很强的抗干扰能力，全息技术被引入到数字水印领域，为保护数字产品提供新的有效途径。本文对计算全息图在数字图像水印技术中的应用进行了深入的研究，主要研究内容和成果如下：

1) 提出用一个聚类中心迭代选择过程来代替聚类中心随机初始化过程，对 FCM (Fuzzy C-Means)聚类算法进行改进。在此基础上，提出一种自适应计算全息图像水印算法。结合人眼视觉掩蔽特性，该水印算法首先利用改进的 FCM 算法在载体图像中自适应地选择适合嵌入的区域，然后通过一个迭代过程将全息水印嵌入其中，具有较好的不可感知性。与传统的 FCM 算法相比，改进的 FCM 算法能有效地避免陷入局部最优解，且收敛速度更快。水印提取时，不需要原始载体图像。实验结果表明，该全息水印算法对 JPEG (Joint Photographic Experts Group)压缩、滤波、叠加噪声和剪切等攻击有较强的鲁棒性；

2) 抗几何攻击的鲁棒性被认为是数字水印技术中最为重要的问题之一。但绝大部分全息图像水印技术都只是侧重研究抗常规攻击的鲁棒性，不能有效地抵抗几何攻击。为此，提出一种抗几何攻击的计算全息水印算法。水印嵌入过程中，该方法通过量化方法将全息水印嵌入到载体图像的小波低频子带。水印检测过程中，首先用基于图像不变质心、尺度不变特征变换和脉冲耦合神经网络的改进几何校正算法对几何失真图像进行校准，然后用校正后的图像进行水印检测。与 Li Zhenhong 等所提的方法相比，改进算法的检测结果不但更准确而且只需少量的辅助数据即可校正几何失真的图像。与其它全息图像水印算法相比，所提的全息水印算法具有更好的抗几何攻击性能。实验表明，算法能有效抵抗旋转、缩放、平移、翻转和旋转-缩放组合、JPEG 压缩、滤波和剪切等几何攻击和常见攻击。

3) 结合计算全息技术，提出一种新颖的抗几何攻击的鲁棒零水印算法。

零水印构造过程中，先对小波变换后的载体图像的低频子带进行分块，然后对每个分块进行奇异值分解并量化它们的最大奇异值，最后用得到的量化矩阵与全息水印构造零水印，并在知识产权(Intellectual Property Rights，IPR)信息数据库注册获得版权保护。检测过程中，先用基于 Zernike 矩和不变质心的改进图像校正算法对几何失真图像进行校准，然后用校正后的图像进行水印检测。与传统的零水印算法及全息水印算法相比，所提的零水印算法具有更好的抗几何攻击性能。实验表明，该算法能有效地抵抗旋转、缩放、平移、翻转和旋转-缩放组合等几何攻击，同时对滤波、加噪声、JPEG 压缩、图像模糊、裁剪和对比度增强等常规攻击也有很强的鲁棒性。

关键词：数字水印；计算全息；小波变换；几何攻击；鲁棒性

ABSTRACT

With the great development of multimedia and internet techniques, the copyright protection and security of digital media become an important and challenging research topic. Digital watermarking which is regarded as an efficient approach for the protection of digital data has been widely explored. Recently, a new approach which uses digital holograms as the watermarks has been introduced because of the encryption characteristic and the property that part of a hologram can still display the whole image. The research conducted in this thesis is focused on the digital watermarking technique using computer generated holograms. The detailed content and the main research results are as followed:

1) Instead of choosing the initial values randomly, the FCM is improved by using an iterative choosing procedure to obtain the initial cluster centers. Then a new adaptive watermarking scheme using computer generated hologram in discrete wavelet transform domain is presented. By utilizing improved fuzzy clustering technique and human visual system, the watermark can be adaptively embedded according to block classification. To keep imperceptibility and robustness, a novel iterative embedding algorithm is adopted to change the to-be-embedded coefficients. Compared with the standard Fuzzy c-means (FCM) clustering, the suggested improved FCM converges more quickly and can avoid local optimum effectively. During the extraction process, the cover image is not needed. The experimental results demonstrate that the proposed watermarking scheme has good robustness to resist JPEG compression, filtering, noise addition and occlusion attacks.
2) Robustness against geometric attacks is one of the most important issues in digital watermarking. However, almost all the existing schemes using digital holograms as the watermarks mainly emphasize the robustness of common attacks and the watermarks cannot be extracted correctly when they suffer geometric attacks. A novel geometric robust

watermarking scheme which uses computer generated holograms as the watermarks is presented. To keep imperceptibility and robustness, a quantization embedding algorithm is adopted to embed the mark hologram into the low frequency sub-band of the wavelet-transformed host image. In the detection process, the geometric distorted watermarked images are recovered first by the proposed improved geometric correction method which is based on the invariant centroid, the scale invariant feature transform and the pulse coupled neural network. Then the mark holograms are extracted from the recovered images. In comparison with the method which was proposed by Li-Zhenhong et al., the suggested improved geometric correction method can estimate the geometric distortion parameters more accurately and need less auxiliary information. Compared with other watermark schemes using digital holograms, the proposed watermarking method has the distinct advantage of robustness to geometric attacks. The experimental results demonstrate that the proposed method has good robustness to resist geometric attacks and common attacks, including rotation, scaling, translation, image flipping, combined attacks, filtering, occlusion, cropping and JPEG (Joint Photographic Experts Group) compression.

3) A novel geometric robust zero-watermarking scheme which uses Computer Generated Holograms as the watermarks is presented. In the zero-watermark construction process, the host image is decomposed with discrete wavelet transform and the low frequency sub-band is divided into nonoverlapping blocks. Singular Value Decomposition is applied to every block. A quantization matrix is obtained by quantizing the largest singular value of each block. Using the quantization matrix and the mark CGH, the zero-watermark which is registered in the database of Intellectual Property Rights (IPR) can be constructed. In the detection process, the geometric distortion parameters of the attacked image are

estimated first by the proposed improved geometric correction method based on the Zernike moments and invariant centroid. Then, the mark hologram is extracted from the recovered image. Compared with traditional zero-watermarking methods and digital hologram watermarking methods, the suggested zero-watermarking scheme provides better performance for resisting geometric attacks. The experimental results demonstrate that the proposed watermarking scheme is robust against rotation, scaling, translation, flipping and combined attack, as well as a variety of common manipulations such as filtering, additive noise, JPEG compression, blurring, cropping and contrast enhancement.

Keywords: Digital watermarking； Computer generated hologram； Wavelet transform；Geometric attack；Robustness.

目 录

Contents