Information Sciences 316 (2015) 40–53

Contents lists available at ScienceDirect

Information Sciences

journal homepage: www.elsevier.com/locate/ins

An improved AQIM watermarking method with minimum-distortion angle quantization and amplitude projection strategy

Yuan-Gen Wang [a], Guopu Zhu [b,*]

[a] School of Information, Zhongkai University of Agriculture and Engineering, Guangzhou 510225, China
[b] Shenzhen Institutes of Advanced Technology, Chinese Academy of Sciences, Shenzhen 518055, China

A R T I C L E I N F O

Article history:
Received 5 June 2014
Received in revised form 7 April 2015
Accepted 11 April 2015
Available online 17 April 2015

Keywords:
Robust watermarking
Angle QIM
Gain attack
Document-to-watermark ratio
Bit error rate

A B S T R A C T

About ten years ago, angle QIM (AQIM) was proposed by Ourique et al. for the purpose of resisting gain attacks. Later, to improve AQIM, Nezhadarya et al. proposed absolute AQIM (AAQIM) and further applied AAQIM to their gradient-based watermarking framework. Both of AQIM and AAQIM have the ability, in principle, to resist gain attacks, but neither of them can achieve optimal performance in terms of angular distortion. In this paper, we propose an improved AQIM watermarking method (IAQIM) with minimum-distortion angle quantization and amplitude projection strategy. IAQIM can not only obtain an optimal performance in terms of angular distortion by using the minimum-distortion angle quantization, but also further reduce the embedding distortion of host signals with the amplitude projection strategy. A theoretical analysis is presented for the performance of the proposed method. Experiments have been conducted to validate the theoretical analysis and to demonstrate the superiority of the proposed IAQIM watermarking method over the existing gain-invariant watermarking methods, including AQIM and AAQIM.
© 2015 Elsevier Inc. All rights reserved.

1. Introduction

Since Chen and Wornell [7] modeled the digital watermarking as communications with side information, great attention has been paid to quantization index modulation (QIM) watermarking methods, in which the amplitude of a host signal is quantized using one of a series of quantizers. Such methods are completely host-interference-free, and thus yield larger watermarking capacity than the spread-spectrum-based methods [4,9]. However, the conventional QIM methods are highly vulnerable to gain attacks (i.e., valumetric distortion), such as amplitude scaling and gamma compensation. These attacks may not degrade the quality of multimedia contents, but can cause an evident increase of the bit error rate (BER)[1] in watermark extraction.

So far, several strategies have been proposed to resist gain attacks, including the use of pilot sequence [24], the construction of the embedding domain being invariant to the gain attacks [1,10,11,22,27–29], and the design of direction-based embedding algorithms, such as angle QIM (AQIM) [18], absolute AQIM (AAQIM) [15], and sample projection approach (SPA) [2]. However, the method using pilot signal [24] is very vulnerable to the malicious attacks that can remove the pilot signal. The methods based on rational dither modulation (RDM) [1,10,22] have the problem of high computational

* Corresponding author. Fax: +86 755 86392299.
E-mail addresses: wygen@mail2.sysu.edu.cn (Y.-G. Wang), guopu.zhu@gmail.com (G. Zhu).
[1] BER is defined as the ratio of the number of erroneously decoded bits to the total number of embedded bits.

http://dx.doi.org/10.1016/j.ins.2015.04.029
0020-0255/© 2015 Elsevier Inc. All rights reserved.

complexity and high peak-to-average power ratio. Logarithmic QIM (LQIM) [11] employs a logarithmic function to improve the perceptual quality of watermarked signal. However, it is not very robust against additive white Gaussian noise (AWGN) attack. The normalized correlation based dither modulation (NC-DM) method [29] embeds watermarks by quantizing the normalized cross correlation between the host signal vector and a random vector. However, like the spread transform dither modulation (STDM) scheme [7], the random vector must be sent to the decoder, which introduces additional information and thus decreases the security of the method. In [27,28], the method, named as amplitude ratio QIM (ARQIM), embeds one watermark bit into the ratio of the amplitudes of the two vectors formed by a number of signal samples. ARQIM achieves good robustness at a low embedding rate. But, the robustness of ARQIM degrades sharply with the increase of its embedding rate. AQIM [18] is the earliest one of the direction-based embedding methods. In the AQIM watermarking, the angle of a host vector is quantized, while its magnitude remains unchanged. Thus the AQIM watermarking is essentially invariant to gain attacks. However, the angular distortion of AQIM is not minimized. Later, to improve AQIM, AAQIM [15] was proposed by quantizing the absolute value of the angle of the host vector instead of the angle itself. But the angle quantization of AAQIM still does not obtain optimal performance in terms of angular distortion. In [2], Akhaee et al. proposed a watermarking method called sample projection approach (SPA), which is a new kind of direction-based embedding methods and thus is also essentially invariant to the gain attacks. However, SPA has two main drawbacks: first, the codelines of SPA are suboptimal in terms of the embedding distortion; second, its embedding domain is vulnerable to the AWGN attack.

This paper focuses on studying the direction-based embedding methods. By analyzing AQIM and AAQIM, we have found that both AQIM and AAQIM have the problem of non-optimal quantization, and AAQIM also introduces extra embedding distortion. To order to solve the problems with AQIM and AAQIM, we propose an improved AQIM method, which introduces a new quantization function that can achieve the optimal performance in terms of angular distortion. Moreover, inspired by [2], the improved AQIM (IAQIM) uses an amplitude projection strategy instead of the amplitude rotation strategy of AQIM to further reduce the embedding distortion of host signals. Then, we present a theoretical analysis on the DWR and BER of the proposed method. The analytical results show that the proposed IAQIM method yields much lower embedding distortion than AQIM and AAQIM. The extensive experiments conducted on both simulated signals and real images show that the IAQIM water-marking method outperforms the existing methods in terms of robustness against various attacks.

The paper is organized as follows. In Section 2, we provide a review and analysis for the AQIM and AAQIM methods. The detailed description of the proposed IAQIM method is presented in Section 3. Section 4 provides a theoretical analysis on the performance of the IAQIM method, which includes the analysis of DWR and BER. Section 5 shows the experimental results, followed by the summary of the paper in Section 6.

2. Review and analysis of angle QIM

Without loss of generality, we consider the case of binary message embedding, i.e., the embedding of the binary alphabet $\mathcal{M} = \{0, 1\}$. The conventional QIM methods embed message by modulating the host signal x to its closest quantization reconstruction point (i.e., codeword) corresponding to the hidden message m ($m \in \mathcal{M}$), as shown in Fig. 1. We denote Δ as quantization step, which is used to trade-off between the robustness and the embedding distortion. In general, Δ may take arbitrary positive real number in the watermarking methods, such as the method in [28] and those with adaptive quantization step [6,16,26]. It can be seen from Fig. 1 that the maximum distortion caused by the message embedding is $\Delta/2$. If the host signal x is uniformly distributed over the quantization cell,[2] the mean-squared embedding distortion will be $\Delta^2/12$, which is in fact the minimum distortion for the flat-host signal [7,13].

2.1. AQIM

The extension of the QIM method to angle was first proposed in [18]. As shown in Fig. 2, we denote OP as a vector from the origin O to the point $P(x_1, x_2)$ in 2-D Cartesian coordinate. OP can also be represented in polar coordinate (r, θ), where θ ($\theta \in (-\pi, \pi]$) denotes the angle formed by the vector OP and the x-axis, and r denotes the radius (amplitude) of OP. In practice, the host signals may be transform coefficients, such as DCT, DFT and DWT, or the gradients of image blocks. AQIM embeds messages by the following steps:

(i) Quantize the angle θ of the host vector OP by

$$Q(\theta) = \Delta \cdot \left\lfloor \frac{\theta + m \cdot \frac{\Delta}{2}}{\Delta} \right\rfloor + m \cdot \frac{\Delta}{2}, \tag{1}$$

where $Q(\cdot)$ and $\lfloor \cdot \rfloor$ are quantization function and floor operation, respectively.

(ii) Rotate the vector OP to the resulting angle $Q(\theta)$ to obtain the watermarked vector OQ, as shown in Fig. 2.

Note that the amplitude r of the vector OP remains unchanged in the rotation. Also note that the quantization step size used in [18] is defined as the distance between a quantization reconstruction point $\bigcirc$ and its nearest neighboring point $\times$,

[2] In fact, this is a most commonly used assumption in QIM watermarking, i.e. the flat-host assumption [20,21].

Download English Version:

https://daneshyari.com/en/article/391518

Download Persian Version:

https://daneshyari.com/article/391518

Daneshyari.com