Computers and Electrical Engineering 000 (2016) 1–15

Contents lists available at ScienceDirect

Computers and Electrical Engineering

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

Data hiding in color halftone images based on new conjugate property

Hai-yang Ding[a,b,*], Yi-xian Yang[a]

[a] Information Security Center, Beijing University of Posts and Telecommunications, Beijing 100876, China
[b] College of Information Engineering, Beijing Institute of Graphic Communication, Beijing 102600, China

ARTICLE INFO

Article history:
Received 21 September 2015
Revised 15 June 2016
Accepted 15 June 2016
Available online xxx

Keywords:
Date hiding
New conjugate
Halftone image
Error diffusion
Dot diffusion

ABSTRACT

This paper proposes two data hiding methods in color halftone images based on new conjugate property. Firstly, implementing and extending previous methods, and analyzing the performance of various methods. Secondly, this paper proposes new conjugate property and applies this property to hide a secret pattern in color halftone images, and two novel methods called data hiding by new color conjugate error diffusion (NCCED) and data hiding by new color conjugate dot diffusion (NCCDD) can be proposed. Using new conjugate property fewer components need to be toggled, as a result the correct decoding rate (CDR) of the revealed pattern will be increased, and the visual effect of halftone images can be improved. Finally, this paper proposes average distortion per pixel (ADPP) to measure toggling distortion in different methods accurately. Experimental results show that NCCED and NCCDD not only have higher CDR than the previous methods, but also provide better visual effect of halftone images.

1. Introduction

Halftone image [1] is a kind of image that only uses black and white to represent an image, and there are several methods to generate the halftone images, such as ordered dithering (OD) [2], error diffusion (ED) [3–5], dot diffusion (DD) [6–8], direct binary search (DBS) [9–12]. Ordered dithering is easier to implement than error diffusion, and error diffused halftone images have better visual quality, but parallel processing cannot be implemented in error diffusion system, and dot diffusion is developed to achieve parallel processing and retain the advantage of error diffusion.

Nowadays, two kinds of halftone watermarking technologies have been developed. The first kind of methods hides a secret bit stream into halftone images and these secret bits can be extracted through certain decoding methods [13–16].

The second kind of methods hides a secret pattern into two or more halftone images, and after decoding process is implemented on the halftone images, the secret pattern can be revealed. This kind of methods is also called as halftone visual cryptography. In 1995, the secret sharing concept [17] was designed and applied in digital images to realize a secret sharing scheme, and which is called visual cryptography (VC) scheme. The (k,n) threshold VC scheme hides a secret pattern into n shares, and revealing pattern only needs the k or more of shares to stack them together. In [18], the implementation process of VC had been demonstrated and a tagged visual cryptography (TVC) had been proposed. However, the generated shares often use meaningless images, when these shares are transmitted over a public channel, they may be suspected

* Corresponding author.
E-mail addresses: o_dhy@163.com (H.-y. Ding), yxyang@bupt.edu.cn (Y.-x. Yang).

http://dx.doi.org/10.1016/j.compeleceng.2016.06.007
0045-7906/

Table 1
Comparisons of various methods.

Name of method and reference	Halftoning method	Halftone image type	Advantages (+) and shortcomings (-)
DHCED [19]	Error diffusion	Gray-scale	+ using conjugate property to hide a secret pattern – only the pixel in the second halftone image can be toggled
DHDCDD [20]	Dot diffusion	Gray-scale	+ using dual conjugate property to hide a secret pattern – only be used in gray-scale halftone images
CCED [21]	Error diffusion	Color	+ using a single conjugate with least distortion to hide a secret image – the effect is not ideal when hiding the pattern in two different halftone images
DCCDD [22]	Dot diffusion	Color	+ hide a secret pattern into two different color halftone images + using dual conjugate property in 3 color components separately + considers the correlation of different channels – the CDR of the revealed pattern can be improved – the visual effect of halftone images can be improved

by malicious attackers. To reduce the chance of attracting attackers halftone visual cryptography has gradually become an important research direction.

Halftone visual cryptography mainly includes hiding a secret pattern into gray-scale halftone images [19,20] or color halftone images [21,22].

In [19], data hiding by conjugate error diffusion (DHCED) was proposed, and this method used conjugate property to hide a secret pattern. The contribution of this method is using conjugate property to hide the pattern, but only the pixel of second halftone image can be toggled to achieve conjugate.

In [20], DHCDD and DHDCDD were proposed. Data hiding by conjugate dot diffusion (DHCDD) is an extended method from DHCED [19]. Data hiding by dual conjugate dot diffusion (DHDCDD) is an improved method based on DHCDD. The contribution of DHDCDD is using dual conjugate property to hide a secret pattern which means in this system one of the pixels from two halftone images can be selected to be toggled, as this pixel derives smaller toggling distortion, but this method only can be used in gray-scale halftone images.

In [21], a method to hide the patterns in error diffused color halftone images was proposed, and which is called conjugate color error diffusion (CCED). Because a color image has 3 channels, CCED uses a single conjugate in the channel with least distortion to hide a secret image, and which is the main contribution of this method, but if hiding the pattern in two different halftone images, the contrast of the revealed pattern is not ideal.

In [22], developing DHDCDD [20] from gray-scale halftone images to color halftone images, a method named data hiding by dual color conjugate dot diffusion (DCCDD) was proposed, which hided the pattern into color dot diffused halftone images. To restrict the hiding distortions between inter-channels, the correlation of different channels was considered in DCCDD. Comparing to the previous method, this method can hide the secret pattern into two different color halftone images, and which is one contribution of this method. Other two advantages of this method is using dual conjugate property in 3 color components separately and considers the correlation of different channels, but in this method both the CDR of revealed pattern and the visual effect of halftone images still can be improved. Comparisons of various methods are shown in Table 1.

The goal of this paper is to design data hiding methods in color halftone images and through these methods both the CDR of revealed pattern and the visual effect of halftone images can be improved.

This paper proposes two data hiding methods in color halftone images based on new conjugate property. Firstly, this paper reviews previous methods, and implements and extends various methods, and analyzes the performance of various methods according to the experimental results. Secondly, this paper proposes new conjugate property and applies this property to hide the secret pattern in color halftone images, and two novel methods called data hiding by new color conjugate error diffusion (NCCED) and data hiding by new color conjugate dot diffusion (NCCDD) can be proposed. Using new conjugate property fewer components need to be toggled, as a result the CDR of the revealed pattern will be increased, and the visual effect of halftone images can be improved. Finally, this paper proposes ADPP to measure toggling distortion in different methods accurately, and this distortion will influence the visual effect of halftone images.

The main contribution of this paper is that proposing new conjugate property and applying this property to hide the secret pattern. The merits of the proposed methods will be reflected in the condition: hiding a secret pattern into two different color halftone images.

The organization of the paper is as follows: Section 2 introduces the related works. Section 3 describes the main works of this paper. Section 4 proposes NCCED and NCCDD. Section 5 presents the experimental results. Finally, conclusion is given in Section 6.

2. Related works

In [20–22], there are 3 main data hiding methods in halftone images, and DHDCDD [20] can be applied in gray-scale halftone images, and CCED [21] and DCCDD [22] can be applied in color halftone images.

Please cite this article as: H.-y. Ding, Y.-x. Yang, Data hiding in color halftone images based on new conjugate property, Computers and Electrical Engineering (2016), http://dx.doi.org/10.1016/j.compeleceng.2016.06.007