Comments and Proofs to Published Paper-A Novel Reversible Robust Watermarking Algorithm Based on a Chaotic System

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Abstract

Information hiding is an emerging research area which includes applications such as copyright management [4], tamper detection and content authentication. Existing chaos optimization and random position selection based watermarking embedding methods make claims for robustness and reversibility; however, reversibility becomes questionable when data capacity is high. In a published paper, authors proposed a watermarking algorithm based on a chaotic system, which claims to be reversible; however, based on our experimental results, the existing method suffers from overflow and underflow issues regardless of initial values.

Keywords: Chaotic mapping, comments to published paper, reversible, watermarking

1 Introduction

Most comments and replies to a published article are ignored; however, data shows that the original papers, comments, and replies were cited 476, 104, and 80 times, respectively [2]. Motivated by the popularity of the paper, we intend to investigate [some of the claims made in] the published article, an article which has certainly made very significant contributions to watermarking research. It is our hope that our comments and replies will be helpful to the original authors, perhaps allowing them to further improve their algorithm.

In the published paper, the authors proposed a novel watermarking scheme using a chaotic function and discrete wavelet transform [3]. Their algorithm is divided into two stages as follows (more details can be found in [1]).

a) Watermark Embedding

b) Watermark Extraction

The rest of the paper is organized as follows. Section 2 explains the limitations of the published algorithm in detail. Section 3 uses experimental results to evaluate the published algorithm. Finally, Section 4 addresses the conclusions of the paper.

2 Limitation of the Published Method

Gu and Gao state that the initial value X_o of their chaotic logistic map plays a vital role in embedding watermarks. In addition, the authors claim that the aid of the initial value prevents overflow and underflow issues. Therefore, by using these initial values and threshold level, the proposed method becomes reversible. However, this method proves to be not only irreversible but also non-embedded when the initial values are absent. Moreover, the existing method avoids overflow and underflow issues in complex images, whereas there is a high probability of overflow and underflow occurrence in smooth images. In this comment paper, we provide evidence to justify these claims.

3 Experimental Results

Example 1 provides evidence for successful embedding, as the authors (Qiaolun Gu and Tiegang Gao) claim in the existing paper [1]. Example 2 proves our claims regarding underflow. In this paper, we only show the underflow example since overflow can be proven in exactly the same.

Example 1:
Figure 1 shows the smaller image data array, which is divided into non-overlapping 6 × 6 sub-blocks and Figure 2 shows the low frequency sub-band LL_1 with a 3 × 3 matrix data array.

The following chaotic map generates the number sequence as shown below;
Seq(k)=3,2,1,4,1,8,2,3,6,7,9,…,
Threshold (T) =4;
Secret bit w=1;

1	1	2	2	1	1
2	1	2	2	2	1
1	1	2	3	1	1
1	2	4	5	1	2
2	1	2	1	1	1
1	1	1	1	1	2

Figure1: Data array of cropped Image (6 × 6)

1	2	1
1	3	1
1	1	1

Figure 2: Data array of sub band LL_1 (3 × 3)

The following steps are followed for the embedding procedure;

Seq(1)=3, (1)

$d_n = b_5 - b_3 = 3-1=2$ (2)

$\Delta+1 = \text{floor}((4-2)/2)+1=2$ (3)

New $b_5=3+2 = 5$ (4)

New $b_3=1-2 = -1$ (5)

In order to obtain the original 6 × 6 block, IIWT (Inverse Integer Wavelet Transform) is applied, as shown in Figure 3. We can see that there is underflow in the new image block; therefore, reversibility is questionable.

1	1	2	2	-1	-1
2	1	2	2	0	-1
1	1	4	5	1	1
1	2	6	7	1	2
2	1	2	1	1	1
1	1	1	1	1	2

Figure 3: Original block with underflow

Therefore, we drop Seq (1) and choose Seq (2), and then follow the same procedure as above:

Seq(2)=2 (6)

$d_n = b_5 - b_2 = 3-2=1$ (7)

$\Delta+1=\text{floor}((4-1)/2)+1=2$ (8)

New $b_5=3+2 = 5$ (9)

New $b_2=2-2 = 0$ (10)

Figure 4 shows the new image block which is obtained using IIWT. It can be seen that there is no underflow; therefore, the operation is successful.

1	1	0	0	1	1
2	1	0	0	2	1
1	1	4	5	1	1
1	2	6	7	1	2
2	1	2	1	1	1
1	1	1	1	1	2

Figure 4: Original block without underflow

Example 2:

The chaotic map generates the number sequence as shown below;

Seq (k)=3,2,1,4,1,8,2,3,6,7,9,…
Threshold (T) =4
Secret bit w=1

1	1	1	1	1	1
2	1	1	1	2	1
1	1	2	3	1	1
1	2	4	5	1	2
2	1	2	1	1	1
1	1	1	1	1	2

Figure 5: Data array of cropped Image (6 × 6)

1	1	1
1	3	1
1	1	1

Figure 6: Data Array of sub band LL_1 (3 × 3)

In the following procedure, we demonstrate that image block becomes non-embedded regardless of initial value.

For instance,

Seq(k)=m, where m=1,2,3,4,6,7,8,9 (11)

$d_n = b_5 - b_m = 3-1=2$ (12)

$\Delta+1=\text{floor}((4-2)/2)+1=2$ (13)

New $b_5=3+2 = 5$ (14)

New $b_m=1-2 = -1$ (15)

The following Figures. 7-14 show that there is underflow in every block for each m=1, 2, 3, 4, 6, 7, 8, 9

-1	-1	1	1	1	1
0	-1	1	1	2	1
1	1	4	5	1	1
1	2	6	7	1	2
2	1	2	1	1	1
1	1	1	1	1	2

Figure 7: Original block with underflow m=1

1	1	-1	-1	1	1
2	1	-1	-1	2	1
1	1	4	5	1	1
1	2	6	7	1	2
2	1	2	1	1	1
1	1	1	1	1	2

Figure 8: Original block with underflow m=2

1	1	1	1	-1	-1
2	1	1	1	0	-1
1	1	4	5	1	1
1	2	6	7	1	2
2	1	2	1	1	1
1	1	1	1	1	2

Figure 9: Original block with underflow m=3

1	1	1	1	1	1
2	1	1	1	2	1
-1	-1	4	5	1	1
-1	0	6	7	1	2
2	1	2	1	1	1
1	1	1	1	1	2

Figure 10: Original block with underflow m=4

1	1	1	1	1	1
2	1	1	1	2	1
1	1	4	5	-1	-1
1	2	6	7	-1	0
2	1	2	1	1	1
1	1	1	1	1	2

Figure 11: Original block with underflow m=6

1	1	1	1	1	1
2	1	1	1	2	1
1	1	4	5	1	1
1	2	6	7	1	2
0	-1	2	1	1	1
-1	-1	1	1	1	2

Figure 12: Original block with underflow m=7

1	1	1	1	1	1
2	1	1	1	2	1
1	1	4	5	1	1
1	2	6	7	1	2
2	1	0	-1	1	1
1	1	-1	-1	1	2

Figure 13: Original block with underflow m=8

1	1	1	1	1	1
2	1	1	1	2	1
1	1	4	5	1	1
1	2	6	7	1	2
2	1	2	1	-1	-1
1	1	1	1	-1	0

Figure 14: Original block with underflow m=9

In summary, underflow will occur regardless of the initial value if we have an image block as shown in example 2. Therefore, a location map is mandatory for classifying the validity of the blocks.

4 Conclusions

The published paper has a significant novelty level in that it used chaos optimization to discover the reversibility space of the scheme. However, in this comment paper, we prove our claim that underflow is unavoidable regardless of the initial value and insist upon the importance of a location map for the published algorithm.

References

[1] Q. Gu and T. Gao, “A novel reversible robust watermarking algorithm based on chaotic system,” *Digital Signal Processing*, vol. 23, no. 1, pp. 213-217, Jan. 2013.

[2] P. R. Krausman, J. R. Morgart and S. S. Rosenstock, “Comments and replies to published papers: advancing science or unnecessary quibbles?,” *Wildlife Society Bulletin*, pp. 208-211. 2003.

[3] S. S. Sujatha1 and M. Mohamed Sathik, “A novel DWT based blind watermarking for image

authentication," *International Journal of Network Security*, vol. 14, no. 4, pp. 223-228, July 2012.

[4] B. Surekha and G. N. Swamy, "Sensitive digital image watermarking for copyright protection," *International Journal of Network Security*, vol. 15, no. 2, pp. 113-121, Mar. 2013.

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