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An Efficient Active Content Reconstruction Based on Adaptive Pixel Permutation

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Abstract:
The capability of reconstructing the original content is one of the most compelling features of digital image authentication schemes. This paper introduces a new model of the content reconstruction problem in self embedding systems, based on an erasure communication channel. The proposed method is based on an alternative approach to spreading the reference information over the whole image. An efficient pseudorandom pixel permutation method permute the reference informations of the pixels in the whole image and can deliver better reconstruction performance. This paper leads to important insights on how permutation schemes should be constructed to achieve optimal performance. After applying this method, it is possible to recover portions of the image that have been cropped out, replaced, or otherwise tampered without accessing the original image. So high-quality reconstruction is still possible, even under extensive tampering.

Keywords— Reconstruction, self embedding system, pseudorandom pixel permutation

I. INTRODUCTION

The capability of reconstructing the original content is one of the most compelling features of digital image authentication schemes. In addition to the content hashes for authentication purposes, an encoder embeds in the image a reconstruction reference, which describes the content, and which can be used by a dedicated decoder to restore the tampered image fragments. Hence the term self-embedding, coined in the original publication [1].

In the most common approach, the reference information is a reduced-quality version of the original image. Alternatives also exist, where the reconstruction reference no longer has a direct interpretation of an image. In [2], it is constructed from the redundancy provided by traditional error correction codes. In [3] content reconstruction is modeled as an irregular sampling problem, and projection onto covex sets are used for restoration. A formulation of the content reconstruction problem in terms of compressing sensing has recently been proposed in [4].

In many schems reference information regarding to a particular image block (i^{th}) is simply embedded into a different block (j^{th}), often chosen pseudorandomly. As a result the the i^{th} block can be recovered only if j^{th} is still authentic. This problem is referred to as the reconstruction dependency. In fact, the decoder needs not to rcover the whole reference stream, but only the necessaary fragments corresponding to the tampered image regions. Since it is not possible to determine a priori which regions will be tampered, the remaining portion of the reference stream eventually turns out as unnecessary and contributes to the waste of the watermark's capacity. This problem is referred to as the reference waste.

Both problems can be solved with proper scheme design. As recently shown, the reference waste can be mitigated by reusing authentic image content, and the reconstruction dependencies can be eliminated by distributing the reference information over the image. In these schemes, the image content is randomly divided into groups, and a random linear projection of each individual group is performed too obtain the reference data. The resulting bits are then pseudo randomly scattered over the image. The reconstruction is possible if the number of tampered elements within each group is below a certain threshold, determined with the use of the binomial distribution. When the threshold is exceeded, approximation techniques may be employed.

Such schemes, where the reconstruction fidelity deteriorates with the tampering rate, are referred to as flexible. Despite the variety of available research, there is no general model of the content reconstruction problem. If an existing scheme needs to be adapted to different requirements, the available experimental results no longer apply, and it is difficult to estimate the impact of the prospective modifications. It is also not clear, how efficiently it is possible to trade-off various system parameters.

This phenomenon is clearly visible by considering the trade-off between the image quality and the restoration conditions. The former is expressed by means of objectively measured distortion of the original image, e.g., using the peak signal to noise ratio (PSNR). The latter is usually the maximum tampering rate, i.e., area of modifications for which the reconstruction is still possible. On the one hand, the scheme from allows for lossless reconstruction with bit-wise accuracy. It is achieved by combining a full-quality reconstruction reference with difference expansion for its embedding. While the resulting stegoimage is significantly distorted, it can be used to perfectly restore the original content, both in the watermarked and the tampered regions. The cost for this superior quality is a limited tampering rate of 3.2%. On the other hand, proposes a scheme which withstands a tampering rate of 59%, but provides only low-quality restoration.

The proposed method is based on an alternative approach to spreading the reference information over the whole image, which has recently been shown to be of critical importance in the application at hand. In this project presents a theoretical analysis of the inherent restoration trade-offs. To improve the content restoration apply efficient seed based pseudorandom pixel permutation method. Here perform an exhaustive reconstruction quality assessment, where the presented reference scheme is compared to five state-of-the-art alternatives in a common evaluation scenario. This paper leads to important insights on how self-embedding schemes should be constructed to achieve optimal performance. The reference authentication system designed according to the presented principles allows for high-quality reconstruction, regardless of the amount of the tampered content.

II. REWIND OF EXISTING SYSTEM

The most recent research on self-embedding focuses on flexible and adaptive schemes. In the flexible system 5 most significant bits of two randomly selected pixels are combined by exclusive disjunction, then grouped with other pixel pairs and embedded into 3 least significant bit-planes of randomly selected image blocks. Depending on the authenticity of individual pixels, the combined 5 bits of a pixel pair can be either fully or partially recovered. The remaining uncertainty is resolved by exploiting local pixel correlations.

In secure and improved self embedding algorithm to combat digital document forgery the authors propose to use a dithered binary version of the image as a reference, and perform the reconstruction by inverse half toning of the recovered watermark. The scheme proposed groups scattered image blocks, and performs linear projection of their discrete cosine transform (DCT) coefficients using a pseudo-random Gaussian matrix. Hence, it spreads the reference information within a single block group. The complete reference bit stream is then scattered over the whole image. During content reconstruction, the necessary coefficients within each individual group are recovered either using composite reconstruction or by compressive sensing.

The authors describe two schemes, with constant-fidelity and with flexible restoration. In the former, the reference information is obtained by randomly ordered 5 most significant bit-planes. The latter uses a pyramidal decomposition of the image blocks, and defines a three-part scalable reference stream. The utilized LT code spreads the information about each image fragment over the image. Content adaptivity has also been demonstrated. An individual image block is represented with one of multiple defined reference rates, depending on the amount of texture. The reconstruction adaptivity presented in stems from an additional quality descriptor which defines several fidelity levels. By controlling the reconstruction quality for each image block individually, it is possible to bias the scheme either toward better quality or better tampering rate. The resulting varying-length reference is then encoded into a constant-length payload in order to exploit the maximum capacity of the watermark scheme. The utilized LT code spreads the information about each image fragment over the image. This scheme, however, fails to exploit the remaining authentic content and is limited by traditional bounds of a general erasure channel.

In content adaptivity individual image block is represented with one of multiple defined reference rates, depending on the amount of texture. The primary objective is to improve the reconstruction quality with simultaneous reduction of the reference payload. One of the defined rates is null, and its corresponding blocks are recovered with the use of inpainting.

III. PROPOSED SYSTEM

The proposed system presents a theoretical analysis of the inherent restoration trade-offs. To improve the content reconstruction, apply efficient seed based pseudorandom pixel permutation method. A permutation (rearrangement) can be described by assigning successive numbers to the objects to be permuted and then giving the order of the objects after the permutation is applied. For example, if there are eight objects1 2 3 4 5 6 7 8 the permutation8 7 6 5 4 3 2 1 reverses the order of the objects. Multi reduce uses permutations of the columns and rows of an image to “quarter” it. First all the even-numbered columns are moved to the left half, while all the odd-numbered columns are moved to the right half. Then the same thing is done to the rows.

This process is then repeated. Permutations preserve loom-controlled availability as described. That is, if an image is weavable, any permutation of it is also. Conversely, if an image is not weavable, then neither is any permutation of it. Permutations can be viewed as pattern generators and hence as tools for weave design. Here are some examples of Multi Reduce applied to a weavable image that is used as a border for Web pages related to weaving. The original image is at the upper left. The number of different permutations of *n* objects becomes astronomical as n gets large. To make any sense of it, it’s necessary to focus on kinds of permutations. Some, like reversal and rotation, may be useful for some purposes but not produce much in the way of variety.

One kind of permutation with some promise permutes blocks of pixels while leaving the pixels within a block unchanged. For example, a 32-column image might be divided into 4blocks of 8 columns each, labeled A, B, C, and D. Permutations rearrange objects without deleting or duplicating any. A more general form of “mutation” allows deletion and/or duplication of objects as well. The permutation notation extends naturally to mutations.

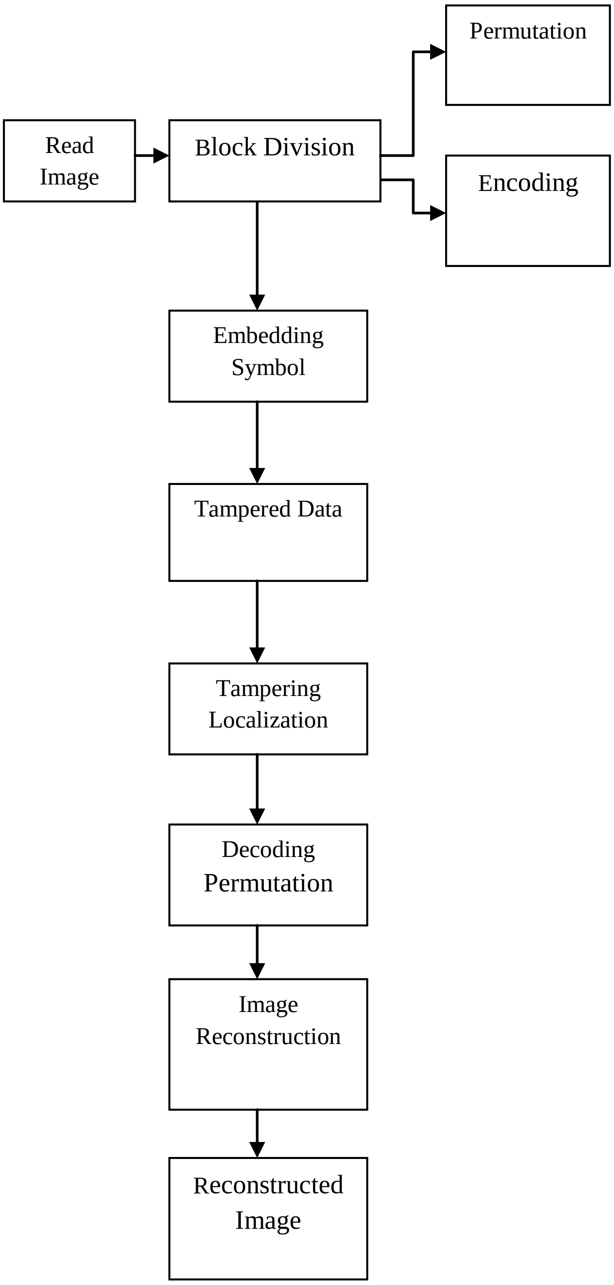

Fig 1: Proposed system architecture

The proposed procedure is sketched in Fig. 1 and the detailed steps are described in the following.

In this first introduce a generic reconstruction framework and the resulting model is referred to as the self recovery model. The operation of many image authentication and reconstruction systems can be summarized in terms of a generic framework, regardless of the assumed formulation of the content reconstruction problem. There are three fundamental properties which differentiate such systems: the reference generation and reconstruction method, the payload encoding method and the data embedding scheme.

Fig 1.a : Original Image

Fig 1.b :Tampered Image

Fig 1.c :Reconstructed Image

A. Block Division

In the block division the image is divided into non-overlapping 8× 8 px blocks. Here use bit substitution for data embedding in the 3 least significant bit-planes. Convert the message to a binary sequence using a encoding technique, where each character is converted to 8-bit binary representation. Divide the binary sequence into fixed-size blocks of length N. Permute each block using key-based randomly generated permutation. Concatenate the permuted blocks to form a permuted binary sequence, which represent the permuted binary sequence. The reconstruction reference generation function performs quantization of the DCT coefficients.

B. Embedding Symbol

In the embedding symbol the reconstruction reference r consists of N b-bit reference blocks. The stream is then divided into constant length B -bit reference symbols X_k: k =1,...,K which are then encoded with the RLF to produce N embedding symbols Y_i. In case an image block is tampered, the decoder marks the corresponding embedding symbol as erased and continues with reference data decoding. The code rate, denoted as $\lambda = K/N$, reflects the rate of the effective payload with respect to the available watermark capacity. Given the probability of decoding error δ, the bound on the reconstruction success for a general erasure channel and a random linear fountain code is

$$M \geq K + \square \ (\delta)$$

$$\gamma \geq \lambda + \square \ (\delta) / N \qquad (1)$$

For an ideal code, the decoder would always be capable of successful decoding if the number of received symbols is equal to the number of input symbols. The equality in (1) defines the bound on the maximal allowed tampering rate, referred to as the γ1 bound. By exploiting the described properties of the self-recovery communication problem, the number of necessary reference symbols becomes reduced

$$\gamma \geq \lambda \rho(\lambda, \gamma)$$

$$\rho(\lambda, \gamma) : R^{+} \times [0,1] \rightarrow [0,1] \qquad (2)$$

$\rho(\lambda, \gamma)$ is the reconstruction demand , i.e., the expected value of the fraction of reference symbols Xi which need to be decoded from the remaining embedding symbols $\{Y_i : e_i = 1\}$ for a given tampering rate $\gamma\square$.

C. Tampering Localization

The tampering locations can be distributed over the whole image and the misalignment between the boundaries of reference blocks and symbols will cause a more precipitous increase of the reconstruction demand. The best possible reconstruction capability is achieved when the tampering in a new reference block r_i yields minimal impact on the reference symbols X_j. Such a situation occurs when the reference blocks and symbols are perfectly aligned or when the erasure pattern is continuous over r_i, e.g., when image blocks i = 1 ,...,N − M are tampered.

$$\rho(\lambda, \gamma) = (1 - M/N) = (1 - \gamma) = \gamma\square \qquad (3)$$

$$\gamma \geq \lambda(1 - M/N) = (1 - \gamma) \Rightarrow \gamma \geq \lambda/\lambda + 1 \qquad (4)$$

D. Reconstruction

Communication of the reconstruction reference to the decoder clearly resembles the erasure channel. Each image block carries a single symbol of the watermark pay-load. Since the erasure (tampering) localization information is intrinsically available after content authentication, the decoder sees the transmitted symbols either as correctly transmitted or erased, for authentic and tampered blocks, respectively. In this derive the reconstruction success bound for a random tampering pattern, where the image blocks for modification are chosen randomly. The main factor that influences the reconstruction demand is the misalignment between the reference blocks and symbols. Three fundamental cases can be distinguished:

hcf (b,B) = b⇔ 1/λ€ N
1 < hcf (b,B) <b
hcf (b,B) =1

hcf (.) is the highest common factor. In the first of the identified cases, *B* is a multiple of *b* and the probability of invalidating a reference symbol can be calculated in a straight forward manner. Since each reference symbols is overlapped by exactly *λ* reference blocks, it will need to be decoded provided that any of the corresponding reference blocks I is required.

IV. EXPERIMENTAL RESULTS

Experimental validation of the proposed content reconstruction model is divided into two main parts. Firstly, to assess the accuracy of the assumed reconstruction demand estimate and validate the theoretical reconstruction success bounds. Second, perform an exhaustive evaluation of the reconstruction quality. The experiments are performed using a reference image authentication system.

A. Reference Image Authentication System

The operation of the reference image authentication scheme follows the general algorithm and principles described. This section merely describes the implementation of the *h, f* and g_b functions. The image is divided into non-overlapping 8×8 px blocks. Here use bit substitution for data embedding in the 3 least significant bit-planes. Such embedding strategy is used by most of alternative schemes, which facilitates fair comparison of the reconstruction performance. The remaining 5 bit-planes are considered as visually important and are transformed into DCT domain for generating the reconstruction reference. Such construction ensures that the embedded watermark does not interfere with the reconstruction reference generation basis.

B. Reconstruction Success Bounds

For the purpose of validating the assumed reconstruction, demand estimate to perform a full content protection →tampering → reconstruction cycle. During the reconstruction process, the decoder records the observed reconstruction demand value *ρ*. This experiment is repeated 250 times for each of the considered values of *b*, and for each 250-point result set, perform a fit to the *φ(γ)* function.

$$\varphi(\gamma)=1-\gamma^{a} \qquad (5)$$

The shape parameter *α* is estimated by solving a nonlinear least squares problem. This experiment clearly demonstrates that the derived theoretical results closely approximate the behavior of the reconstruction demand. If 1 < hcf (b, B) < b the assumed estimate is potentially least accurate.

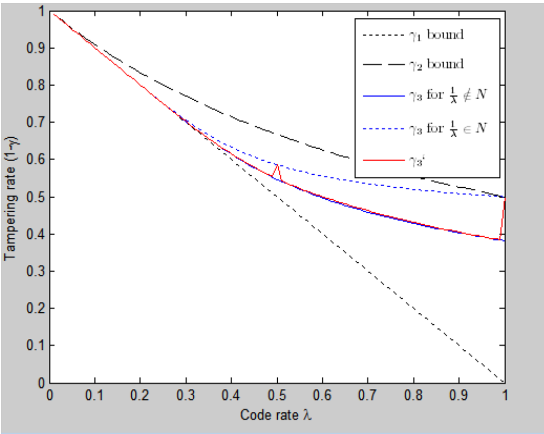

Fig 2: Derived Reconstruction Success Bound

The obtained results also show the validity of the theoretical reconstruction success bounds. The empirical bound between the reconstruction success and failure coincides with the *γ*3 bound. Here also observe that for the *λ* =1 case the reconstruction success bound reaches the optimistic bound of *γ*2.

The purpose of the next experiment was to validate all of the introduced bounds: *γ*1, *γ*2 and *γ*3. In each iteration encoded the image with a random *λ* setting, tampered a random fraction $\tilde{\gamma}$ of the available image blocks, and attempted to perform content reconstruction. The evaluation for done with different pseudo random number generator.

C. Reconstruction Quality Evaluation

This experiment to perform exhaustive evaluation of the reconstruction quality. In addition to the presented reference algorithm consider 5 of state-of-the-art self-embedding scheme, both with constant and with flexible reconstruction quality. In order to facilitate fair comparison of the reconstruction performance, have reimplemented the schemes in a common evaluation framework. The proposed algorithm yielded the best quality.

TABLE I
RECONSTRUCTION PSNR FOR VARIOUS □□

Scheme	0.050	0.100	0.200	0.300	0.475	γ□ max
[4]	37.2	38.4	31.7	29.1	27.0	0.60
[13]	28.5	28.4	28.4	28.4	28.4	0.59
[14]	37.3	35.6	33.3	31.6	29.2	0.54
proposed	36.4	36.4	36.4	36.4	36.4	0.50

Large amount of high-energy DCT coefficients causes reference value saturation, most visible. The fidelity is limited by reconstruction artifacts, typical for this scheme when dealing with larger tampering rates.

V. CONCLUSION

In conclusion the presented analysis gives new insights into the inherent self-recovery trade-offs. This paper introduces a new model of the content reconstruction problem in self embedding systems, based on an erasure communication channel. To have shown that the erasure channel is a valid model of the content reconstruction problem. The proposed method is based on an alternative approach to spreading the reference information over the whole image. An efficient pseudorandom pixel permutation method permute the reference informations of the pixels in the whole image and can deliver better reconstruction performance. Thus this paper leads to important insights on how permutation schemes should be constructed to achieve optimal performance. After applying this method, it is possible to recover portions of the image that have been cropped out, replaced, or otherwise tampered without accessing the original image. So high-quality reconstruction is still possible, even under extensive tampering.

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