A GEOMETRICAL ROBUST IMAGE DATA HIDING SCHEME BASED ON CONTOURLET TRANSFORM

DUC M. DUONG, DUC A. DUONG

ABSTRACT

In this paper, we present a new approach for data hiding in digital images by using multiple embedded stages. The new scheme involves feature point detector that orient for a novel Contourlet transform-hiding algorithm. By this way, our model can withstand geometric, desynchronization attacks and other common attacks with a high capacity. The resulting watermarking scheme is suitable for public watermarking applications, where the original image is not available for watermark extraction. Experimental results demonstrate that our proposed technique is robust to a wide range of attacks.

Keywords. data hiding, geometrical attacks, watermarking Contourlet transform,

1. INTRODUCTION

One of the chief difficulties in watermarking or data hiding scheme is to make the safe level of robustness resistant desynchronization and other geometric attacks. Until now, the effective ways to resist to geometric attacks is still a challenging problem and a one of the research focuses in the field of watermarking.

The main issue is the slight geometric manipulation to the watermarked image such as scaling or rotation, which could significantly reduce the possibility of successful watermark retrieval, providing that the watermarking extractor have no knowledge of the distortion parameters. In another word, geometric distortion can easily introduce synchronization errors into the watermark extracting process.

In [10], we got significant results in payload, signal processing and some geometric attacks such as cropping and removing. However, our scheme still failed in most of geometric and affine transformations. In this proposal, we use content of the image to achieve synchronization and a Contourlet embedding scheme to embed the message. Firstly, we use Harris detector to obtain feature points with inherent geometrical robustness. Then we utilize Delaunay tessellation [14] to partition the image into different triangles. The center coordinate vector of each Delaunay triangle will be considered as synchronization information, which is embedded inside these triangles by using a lattice Quantization Index Modulation (QIM) [12] scheme on Neighborhood Pixel Ratio (NPR) [5]. After that, the Contourlet based algorithm is used to embed communication message into the Contourlet transform of the image.

2. RELATED WORKS

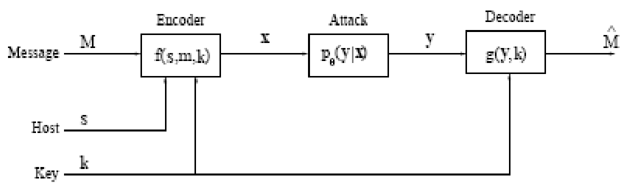
2.1. Geometrical distortions

Geometric distortions can be decomposed into two classes. The first classes of watermarking schemes are self-synchronization schemes. In which they use periodical properties of the mark, invariant properties of transforms, template insertion or information provided by the original image to counter geometrical distortions. Other classes of watermarking schemes using the image content that embed and detect the mark through a content descriptor defined by salient points.

2.2. Mathematical model

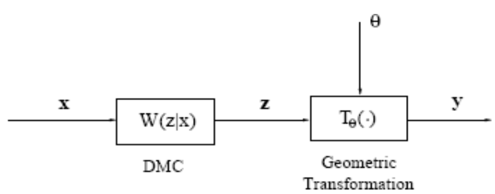
P. Moulin [2, 3] stated and proved for the existence of universal/optimal decoders under geometric or desynchronization attacks.

Data are to be embedded at a rate of R bits per sample (pixel) in a host signal (image). The marked sequence x is subject to attacks, resulting in a degraded sequence y. The decoder returns an estimate $\hat{M} = \psi_n(\text{y}; \text{ k})$ of the message that was sent. The side information k may be a cryptographic key, independent of S (*blind watermarking*); k may also contain full information about S (*nonblind-watermarking*).



Figurre 1. Communication model for watermarking and data hiding [2]

Referring to Fig. 2, the attack is modeled by the cascade of a fixed memoryless channel $W(z|x)$ and an invertible global mapping T_θ representing a desynchronization attack. Therefore, y = $T_\theta z$, where z is generated according to the product probability density function (pdf) $W^n(.|\text{x})$.



Figurre 2. Model for geometric attacks [2]

2.3. Harris detector and Delaunay tessellation

Among various feature point detectors, the Harris detector [13] shows the best performance in terms of restoration. This detector uses differential features of the image. The Harris points are geometrically stable under various image-processing attacks. Harris detector determines significant points in an image by considering the points at which the gradient is at a maximum, above a specified threshold. Our proposal algorithm apply smoothing filter to weed out weaker points to find the feature points with more robustness. Then we can use that feature points combining with Delaunay tessellation method [14] to calculate a unique set of triangles. If there is any point alters then only triangles sharing that point are affected.

2.4. Neighborhood Pixel Ratio (NPR)

In [5], authors call each Delaunay triangle of the image as T_i. The weight $w(T_i)$ of a T_i is defined as follows. A counter, initialized to zero, is associated to T_i. For each pixel *p* inside T_i, check for its eight neighbors: if more than three neighbors of *p* have intensity values larger than a threshold T_L, the counter corresponding to T_i is incremented. $w(T_i)$ is defined as:

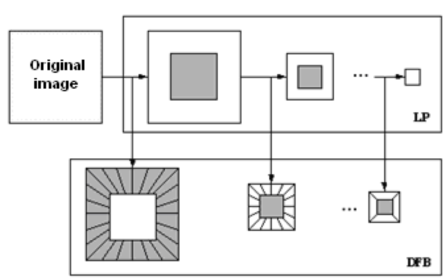
$$\frac{counter}{area_i} \tag{1}$$

where $area_i$ denotes the area in pixels of T_i (~ NPR).

2.5. Contourlet transform

Do and Vetterli [9] developed the Contourlet transform based on an efficient two-dimensional multiscale and directional filter bank that can deal effectively with images having smooth contours. Contourlet not only possess the main features of wavelets but also offer a high degree of directionality and anisotropy.

The primary goal of the Contourlet construction was to obtain a sparse expansion for typical images that are piecewise smooth away from *smooth contours*. Two-dimensional wavelets, lack directionality and are only good at catching *point* discontinuities, but do not capture the *geometrical smoothness* of the contours. This issue is accomplished by combining the Laplacian Pyramid (LP) with a directional filter bank DFB at each scale. Due to this cascade structure, multi-scale and directional decomposition stages in the Contourlet transform are independent of each other. One can decompose each scale into any arbitrary power of two's number of directions, and different scales can be decomposed into different numbers of directions. This feature makes contours a unique transform that can achieve a high level of flexibility in decomposition while being close to critically sampled.

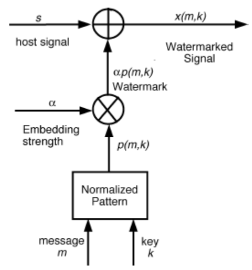


Figurre 3. Contourlet filter bank [9]

2.6. Secure Spread Spectrum Modulation (SSSM)

The application of SSSM [11] to data hiding is illustrated in Fig 4. The significant point is present at secure key k. Message m and key k are normalized before mixed with host signal s. Strength factor α is a pre-defined, used to adjust magnitude of change. Formulas suggested by Cox et al. [11] as follows:

$$\hat{I} = s + \alpha m, \quad \hat{I} = s(1+\alpha m), \quad \hat{I} = se^{\alpha m}$$



Figurre 4. SSSM model [11]

3. THE PROPOSED SCHEME

In this scheme, we develop our model in [10] and increased-value is based upon some other researches. The idea is based on mathematical arguments and results from [2, 3]. In [5], the authors built a model with a key-dependent triangulation, in which they investigated and proposed new concept for gray image, NPR can be seen as a robust embedded domain in many geometrical attacks. Researchers in [4] proved that center coordinate vectors of Delaunay triangles built from feature points are valuable information to resynchronization after geometrical distortions. Review Moulin stated in [2, 3], Generalized Maximum Likelihood and lattice QIM should be used.

Look at our remains in [10], if we can re-construct the geometric attacked watermarked image to the original shape, Contourlet-based algorithm can be continued without difficulty. Fortunately, geometrical distortion and affine transformation named A is invertible through an inverted affine transformation A^{-1}. Therefore, we design the model by two stages. The first stage, we embed information to re-construct the watermarked image if there is geometric attack. Then we use QIM to embed center coordinate vectors to NPR domain. The second stage embed hidden message. By this way, we satisfy two requirements from [2, 3]. In [10] we described second stage in detail.

3.1. Embedding process

The embedded process is executed in two stages. Each stage is responsible for one task. At first stage, we aim to embed information to restore the image in case of geometric distortion attacks. The hidden message is embedded in second stage, based on Contourlet transform. The embedded algorithm is described as follows:

Stage 1:

1. Extract feature points from the original image using Harris detector.

2. Utilize Delaunay tessellation of feature points from Step 1. to partition the image into different N triangles T_i (i=1..N).

3. Calculate center coordinate vector of each Delaunay triangle. Their vector is represented by a binary bit sequence. For example, with coordinates pairs (92, 107), binary bit sequence is (0001011100, 0001101011).

4. Calculate NPR of each triangle as described in [5]. Naming NPR of each T_i is $w(T_i)$.

5. Index set of triangles. Divide into two subsets, first subset include triangles 1... N/2-1, second from N/2...N. Call each triangle in the first subset is O_i, in the second subset is Z_i.

6. Embed information from step 3 to image using rule:

- If 0 is embedded, modify pixels to have $w(O_i) > w(Z_i)$ (2)

- If 1 is embedded, modify pixels to have $w(O_i) < w(Z_i)$

Stage 2:

1. Partition image from first stage to odd and even descriptions.

2. Process Contourlet transform on 2 descriptions

3. Embed message using SSSM on odd sub-band has max energy E.

$$E_{j,l} = \frac{1}{MN}\sum_{m=1}^{M}\sum_{n=1}^{N}\left|d_{j,k}^{(l)_j}(m,n)\right|^2 \quad (3)$$

By the way

- If embed 1: Odd-coefficient = 1.2 * Even-coefficient (4)

- If embed 0: Odd-coefficient = 0.9 * Even-coefficient

4. Reconstruct image using Invert Contourlet transform ➔ odd watermarked image.

5. Process Contourlet transform on odd watermarked image.

6. QIM on low pass coefficients.

7. Reconstruct image using Invert Contourlet transform ➔ Contourlet watermarked image.

3.2. Extracting process

In this process, we first confirm yes or no a geometric distortion applied on marked image by comparing current information with data extracted from synchronization information embedded in first stage. If there is difference, we apply inverted transformation to restore the original shape.

After that, the message will be extract follow by:

1) *Extract follow SSSM on odd description:*

1. Partition reconstructed watermarked image to odd and even descriptions

2. Process Contourlet transform on 2 descriptions, find sub-band has max energy

3. Extract: - Extract 1 if odd coefficient > even coefficient (5)

- Extract 0 if odd coefficient <= even coefficient

2) *Extract follow QIM on low coefficients:*

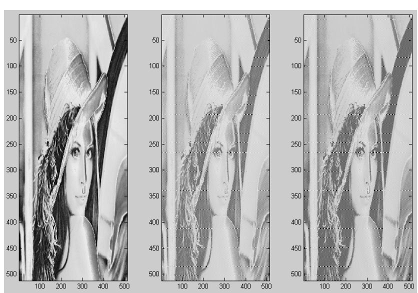
1. Process Contourlet transform on reconstructed watermarked image

2. Extract on low Contourlet coefficients using Nearest Grid Point algorithm.

4. ANALYSIS AND EXPERIMENTAL RESULTS

As the results testing the proposed method, it not only get a high capacity but also robustness. However, its high robustness is shown in geometrical attacks and there are a large numbers of attacked kinds. The capacity is high because host is a color image.

In our experiment, we use Lena gray-image 512 × 512 (8 bits/pixel) hiding a binary logo image 64 × 64 (4096 bits). Original image is decomposed by Pyramidal Directional Filter Bank at three levels with corresponding direction are zero, two and three.



Figurre 5. Host image – Even description – Odd description

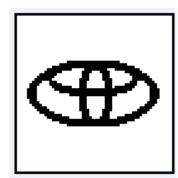


Figure 6. Embedded message
W – 64 × 64

To evaluate the performance of proposed watermarking algorithm, we use PSNR (Peak signal to Noise Ratio) and BER (Bit Error Ratio).

$$PSNR = 10\log\frac{MxNx255^2}{\sum_{i=0}^{M-1}\sum_{j=0}^{N-1}(I_0(i,j)-I_W(i,j))^2} \quad (4)$$

with I_0 is original image and I_w is watermarked image. And

$$NC = \frac{\sum_{i=1}^{P}\sum_{j=1}^{Q}[W(i,j)W'(i,j)]}{\sum_{i=1}^{P}\sum_{j=1}^{Q}[W(i,j)]^2} \quad (5)$$

with W is original message and W' is extracted message using proposed algorithm.

Table 1. Comparision with Wang sheme [4]

	Wang [4]	**Ours**
Capacity	5120	4096
PSNR	46.68	45.68

We use StirMark 4.0 [7] to do geometrical attacks that include scaling rotation, general affine transformation, JPEG, cropping and many common signal processes. Parameters of attacks are same in [8]. The comparison between three algorithms use Lena image 512 × 512. The results are described in table II.

Table 2. Robust results under attacks

BER of Algorithm in attacks	**Dong [8]**	**Wang [4]**	**Ours**
Scaling	0.002	0	0
Rotation	0	0	0
General geometric affine transformations	0.001	0.002	0.002
JPEG	0	0.012	0.001
Cropping	(17 rows, 5 cols)	5%	5%
	0.516	0.001	0.001
Gauss noise 2%	-	-	0.05

Based on the experimental results, our scheme is highe about robust to resist both geometrical attacks and common signal processing. Our scheme obviously equals and exceeds to that of Wang's method [4] and Dong's [8], especially with JPEG and Gauss noise, cropping.

5. CONCLUSIONS

In this paper, we propose the new image data hiding scheme with high capacity and strong robustness in gray image. The strength of the proposed scheme is demonstrated through successful watermark detection after various common attacks. First, it proposes using Contourlet transform corresponding with QIM that allow embedding a high payload because of its flexible in chosen levels and directions transformation without reconstructed errors. Second, by embedding center coordinate vectors of Delaunay triangles in NPR correlation, our algorithm guarantees to extract enough synchronization information efficiently and exactly at a low computational cost. The last and the most important, our scheme proposed the way to combine two professional algorithms in two stages at encoder and decoder. By this way, our scheme can get a high capacity, strong robustness resistant geometric attacks with low computational cost.

REFERENCES

1. Harris and M. Stephen - A combined corner and edge detector”, In 4th Alvey Vision Conf, 1988, pp. 147-151.
2. Pierre Moulin - Universal Decoding of Watermarks Under Geometric Attacks, Information Theory, 2006 IEEE International Symposium, July 2006, pp. 2353-2357.
3. Pierre Moulin - On the Optimal Structure of Watermark Decoders Under Desynchronization Attacks, Image Processing, 2006 IEEE International Conference, 2006, pp. 2589-2592.
4. Peizhong Lu and Dan Wang - A Geometrical Robust Image Data hiding scheme using FCA-based resynchronization, 9th International Workshop, Information Hiding‘07, LNCS 4567, 2007, pp. 267-278.
5. Shiyan Hu - Geometric-invariant image watermarking by key-dependent triangulation, Informatica, 2008, pp.169-181.
6. P. Bas, J-m. Chassery, B. Macq - Geometrically invariant watermarking using feature points, IEEE Trans. on Image Processing **11** (2002) 1014-1028.
7. F.A.P. Petitcolas, StirMark 4.0, 2006.
8. Ping Dong, Jovan G. Brankov, Nikolas P. Galatsanos, Yongyi Yang, Franck Davoine - Digital watermarking robust to geometric distortions, Image Processing, IEEE Transactions **14** (12) (2005) 2140-2150.
9. Minh N. Do, Duncan D. and Y. Po - Directional Multiscale Modeling of Images using the Contourlet transform, IEEE Transactions on image processing, 2006.
10. Duc Minh Duong, Duc Anh Duong - Digital image watermarking in Contourlet transform domain, Journal of Science and Technology, Vietnam **46** (5A) (2008) 135-145.
11. Cox I. J., Kilian J., Leighton F. T., Shamoon T. - Secure spread spectrum watermarking for multimedia, Image Processing, IEEE Transactions **6** (12) (1997)1673-1687.
12. Chen and G. W. Wornell - Quantization index modulation: a class of provably good methods for digital watermarking and information embedding, IEEE Transactions on Information Theory **47** (4) (2001) 1423-1443.
13. Harris and M. J. Stephens - A combined corner and edge detector, Vision Conference, 1988, pp. 147-152.
14. De Berg, Mark - Otfried Cheong, Marc van Kreveld, Mark Overmars, Computational Geometry: Algorithms and Applications, Springer-Verlag, ISBN 978-3-540-77973-5, 2008.

Address:

Received June 16, 2010

HCMC University of Science, Ho Chi Minh City, Vietnam.