Imperceptible Image Watermarking based on Chinese Remainder Theorem over the Edges

Prajanto Wahyu Adi
Department of Informatics Engineering
Universitas Dian Nuswantoro (UDINUS)
Semarang, Indonesia
prajanto@dsn.dinus.ac.id

Yani Parti Astuti
Department of Informatics Engineering
Universitas Dian Nuswantoro (UDINUS)
Semarang, Indonesia
yanipartuastuti@dsn.dinus.ac.id

Egia Rosi Subhiyakto
Department of Informatics Engineering
Universitas Dian Nuswantoro (UDINUS)
Semarang, Indonesia
egia@dsn.dinus.ac.id

***Abstract*—This paper introduced a watermarking method using the CRT and Canny Algorithm that able to improve the imperceptibility of watermarked image and preserving the robustness of watermark image as well. The classical CRT algorithm is spread the watermark bits evenly on the image area. It causes significant degradation when the embedding location lies on the least significant region or in the homogeny area. Otherwise, the proposed method embeds the watermark on the edges of the image which have significant difference value to maintain the imperceptibility. The Canny algorithm is used to indexing the embedding location based on the filtering output of host image. The watermark is then embedded into the host image using pair-wise coprime integers of 6 and 11 within the CRT modulo. The results show that the proposed method has significant improvement in the quality of watermarked image with the average value of 0.9995 compared to the CRT method which results in value of 0.9985. In compression and additive noise attacks the CRT has average values of 0.6618 and 0.9750, while the proposed method results in similar values of 0.6616 and 0.9752 respectively. These prove that the proposed method is able to preserve the robustness while improving the imperceptibility.**

Keywords—watermarking; Chinese Remainder Theorem; Canny edge detector

I. Introduction

Ease of sharing digital medium raises concerns about copyright violations [1]. Therefore the development of method is needed to overcome the problem. Watermarking is a process of inserting information on digital medium that able to protect the ownership of digital medium. The embedded information called watermark can be used as a proof of ownership. It can be extracted using certain technique to get the information therein. The watermark can be an image, audio, or video. In its development, the digital image becomes the most used medium in watermarking [2].

From the numerous developments in the field of watermarking, it can be classified by the working domain, type of data, visibility, and application area [3]. Based on visibility, the watermarking method can be differentiated into visible and invisible watermarking. In computer science, visible watermarking is no longer developed because it disturbs the image. Therefore, the term watermarking is used as a default in the development of invisible watermarking. At the moment, the most widely used classification in watermarking is based on domain used which categorized into transform and spatial domain. The transform domain method has a high robustness against several process which can damage watermark [4], but larger in computational cost. Contrary, the spatial domain is lower in complexity but there is as a trade-off between the image quality and the robustness. One of the best method in spatial domain watermarking is a Chinese Remainder Theorem algorithm [5], it has high robustness against additive noise and perform well in compression process. It can also be expanded into Discrete Cosine Transform domain [6][7]. Although the performance is average compared to Discrete Wavelet Transform [8], Lifting Wavelet Transform[9], nor Integer Wavelet Transform [1].

The CRT algorithm results in suboptimal image quality or imperceptibility. Hence, this paper is proposed an edge embedding scheme in CRT because the human vision is less sensitive against the minor change as the process of embedding in the edge of image [10]. The watermark bits are embedded over the edges of the image through a Canny algorithm to determine the embedding location. Canny is an optimum edge detection scheme [11] that has superiority among other algorithms [12] and commonly used until now [13]. The proposed method aims to optimize the imperceptibility and maintaining the robustness as well.

II. Chinese Remainder Theorem (CRT)

In number theory and cryptography, the fundamental of CRT is the possibility of reconstructing a certain range integers from their modular residues within pair-wise coprime integer [14]. In field of watermarking, this method was advanced by [5] to embed the watermark into pixel value of X. Let:

$$X \equiv r_i \left(\bmod m_i \right) \quad (1)$$

where r_i is the *i-th* residue and X is integer value that can be expressed as

$$X \equiv \left(\sum_{i=1}^{s} r_i \frac{M}{m_i} k_i \right) \bmod M \quad (2)$$

where m_i are pair-wise coprime of s set integers and M the modulo which result from

$$M = \prod_{i=1}^{s} m_i \quad (3)$$

and k_i are calculated until meet the (4) condition

$$\left(k_i \frac{M}{m_i} \right) \bmod m_i = 1 \quad (4)$$

The embedding scenario is to alter the value of X such that set r_i are satisfied the condition determined by the watermark bits value. The modulo are determined by the number of s and the values of r_i as show in (1) until (3). The M value should close to the maximum value of 6 bits integer which represents the pixel value. The CRT is spread the watermark bits evenly on the image pixel. It causes significant damage when the embedding location lies on the least significant region or in the homogeny area. Therefore, the authors proposed a method to embed the watermark on the edges of the image which have significant difference value, so it will not degrade the quality of watermarked images

III. The Proposed Method

The proposed method is started with filtering the host image using the Canny operator to get the edge index. And then it used to determine the index of the pixel to be embedded with the watermark bits.

A. Embedding

This scheme begin with determining the pair-wise coprime integer according to the previous research by [5] which has closest value to the 6-bit integer 2^6. Fig. 1 describes the embedding is as follows:

1) Determine the pair-wise coprime integer 6 and 11 as m_1 and m_2 respectively.
2) Filter the host image with the Canny operator
3) Indexing pixel that produce value of 1 from the filtering process
4) Get the integer value of 6 least significant bit of the indexed pixels
5) Apply CRT on the indexed pixel X to get the pair-wise residue r_1 and r_2:

$$r_1 = X \bmod m_1 \quad (5)$$

$$r_2 = X \bmod m_2 \quad (6)$$

6) Embeds the watermark bits w by altering X until satisfied the following conditions:

$$r_1 \begin{cases} \geq r_2 & , w = 1 \\ < r_2 & , w = 0 \end{cases} \quad (7)$$

X is added and subtracted using an increment value iteratively until (7) is satisfied.

7) Repeat the step 1 until 6 until all watermark bits are embedded.

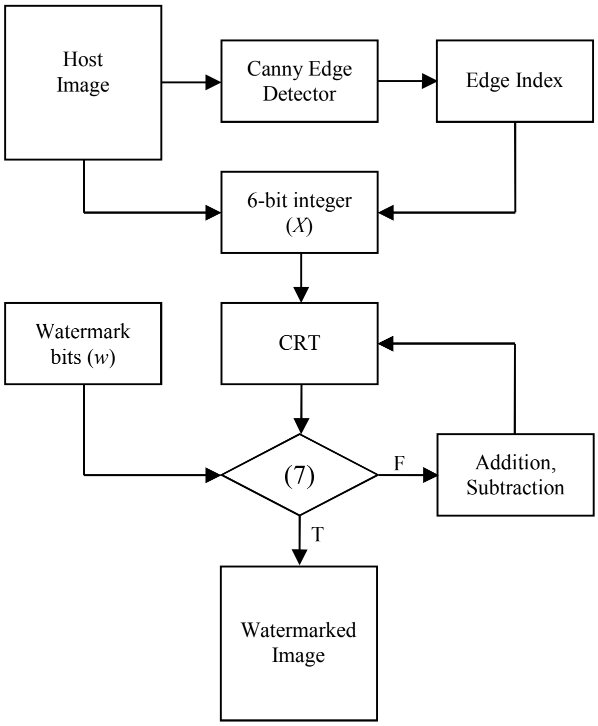


Fig. 1. Embedding Scheme

B. Extraction

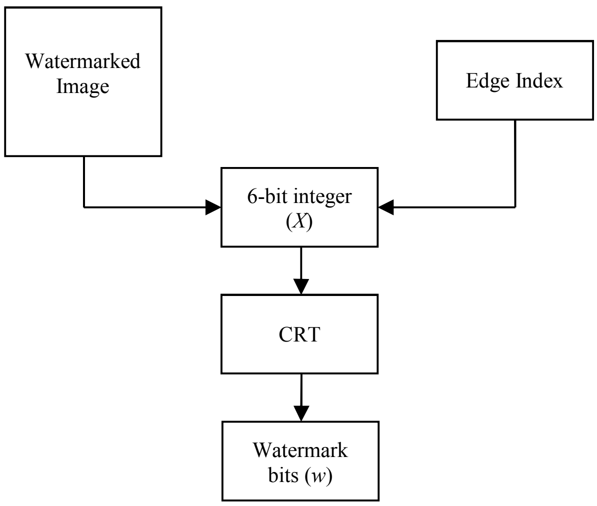


Fig. 2. Extraction Scheme

In extraction scheme, the edge index is used to determine location of the pixel that will be extracted using CRT modulo as shown in Fig.2:

1) Get the edge index to determine the watermark location on the watermarked image
2) Get the integer value of 6 least significant bit of the indexed location
3) Apply CRT on the indexed pixel X to get the pair-wise residue r_1 and r_2 using (5) and (6) respectively
4) Determine the watermark bits w according to the condition:

$$w = \begin{cases} 1 & , r_1 \geq r_2 \\ 0 & , r_1 < r_2 \end{cases} \quad (8)$$

5) Repeat the step 1 until 4 until all watermark bits are extracted.

IV. Results and Discussions

Ten standard grayscale images with size of 512x512 are used as host images. Meanwhile, a binary image of UDINUS logo with size of 128x128 is used as watermark image. The dataset is presented in Fig. 3.

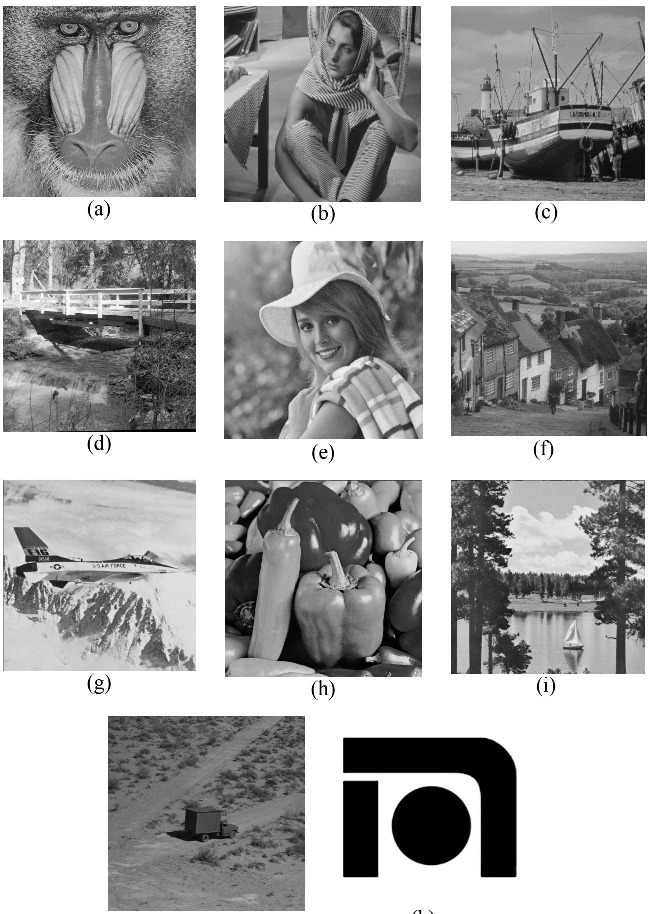


Fig. 3. The host images: (a) Baboon, (b) Barbara, (c) Boat, (d) Bridge, (e) Elaine, (f) Goldhill, (g) Jet, (h) Peppers, (i) Sailboat, (j) Truck; and (k) the watermark UDINUS Logo

To ensure stable result, the integer value of 0 until 9 is used as host images indexes of the Baboon until Truck respectively, and then used as a seed value to generate the edge index using pseudorandom number generator. The edge indexes are then used to determine the embedding location.

A. *Imperceptibility*

The quality of the watermarked images are measured using Structural Similarity (SSIM) [15] due to its capability of measuring image quality in accordance with the human vision. The Table I shows that the proposed method successfully improved the quality of the watermarked images. The average image quality of CRT method is 0.9985 and the proposed method is 0.9995. Fig. 3 shows that the improvement is significant in scale of SSIM, the quality of the images lie above 99.9% which is almost perfect.

The CRT spread the watermark bits evenly on the image pixel. It causes significant degradation when the embedding location lies on the least significant region or in the homogeny area. Otherwise, the proposed method embedding the watermark on the edges of the image which have significant difference value, so it will not damage the watermarked images.

TABLE I. Quality of Watermarked Images

Images	**CRT**	**Proposed**
Baboon	0.9994	0.9998
Barbara	0.9985	0.9996
Boat	0.9977	0.9994
Bridge	0.9994	0.9997
Elaine	0.9986	0.9991
Goldhill	0.9986	0.9994
Jet	0.9974	0.9995
Peppers	0.9981	0.9994
Sailboat	0.9988	0.9997
Truck	0.9984	0.9992
Average	**0.9985**	**0.9995**

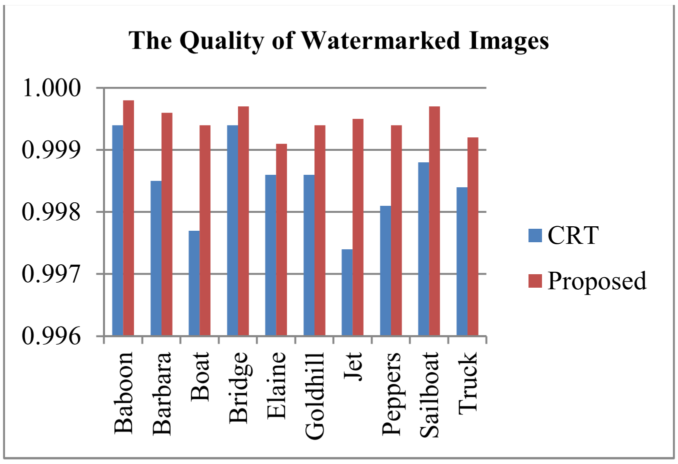


Fig. 3 Quality of Watermarked Images

B. Robustness

The Normalized Correlation (NC) is used to measure the watermark robustness against commonly used attacks i.e. JPEG2000 compression with compression ratio of 3 and additive noise 'salt and pepper' with 5% of density.

TABLE II. ROBUSTNESS OF WATERMARK IMAGES

Images	Compression		Additive Noise	
	CRT	Proposed	CRT	Proposed
Baboon	0.5264	0.5001	0.9789	0.9760
Barbara	0.6863	0.7023	0.9738	0.9742
Boat	0.7255	0.7771	0.9741	0.9749
Bridge	0.5689	0.5290	0.9757	0.9769
Elaine	0.6603	0.6484	0.9743	0.9721
Goldhill	0.6651	0.6548	0.9759	0.9762
Jet	0.7402	0.7977	0.9734	0.9768
Peppers	0.6921	0.6985	0.9760	0.9763
Sailboat	0.6555	0.6450	0.9744	0.9739
Truck	0.6980	0.6634	0.9739	0.9745
Average	**0.6618**	**0.6616**	**0.9750**	**0.9752**

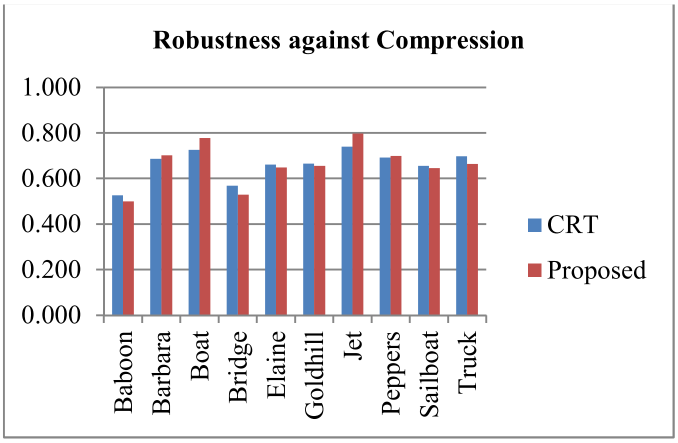


Fig. 4. Robustness against Compression

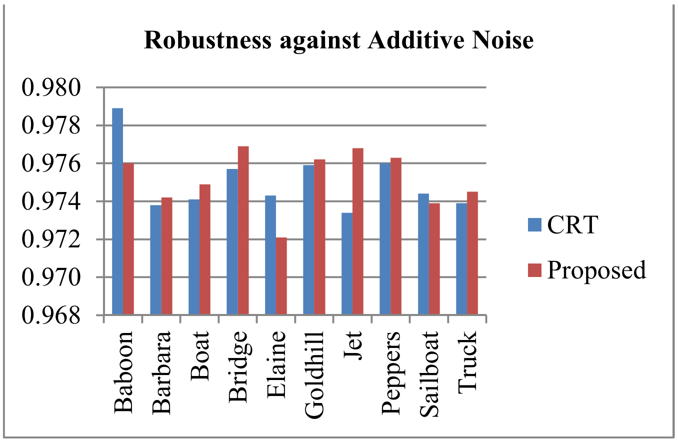
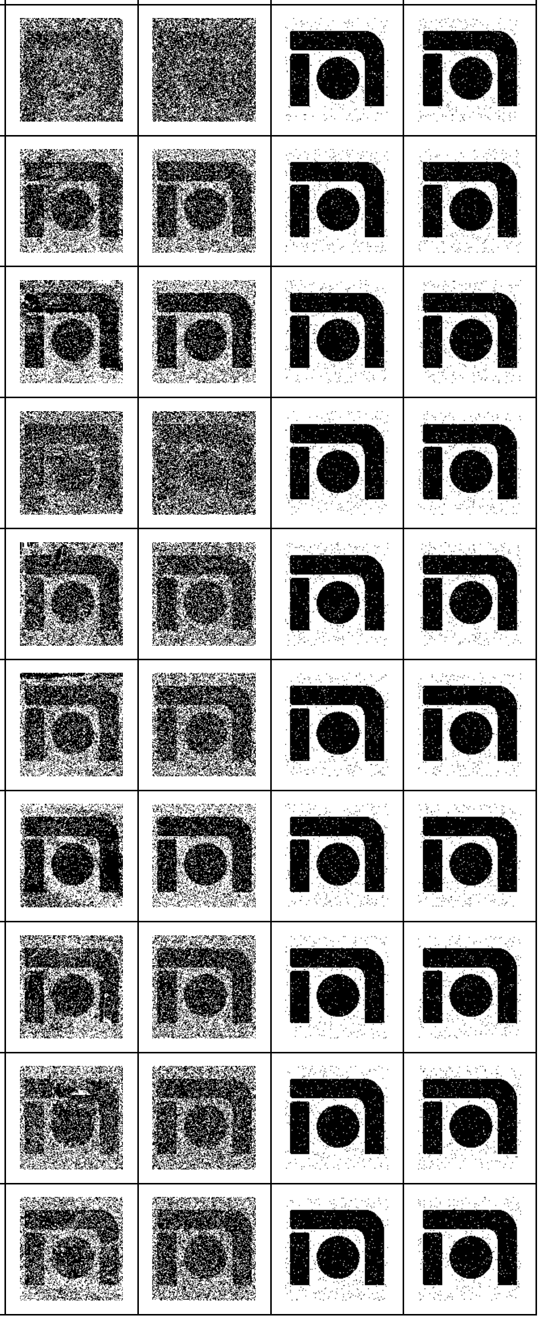


Fig. 5 Robustness against Additive Noise

Table II and Fig. 4 show that the CRT and the proposed method have average robustness against compression 0.6618 and 0.6616 respectively. Meanwhile additive noise attack the average robustness of CRT and proposed method is 0.9750 and 0.9752 respectively as shown in Fig. 5. In addition to the robustness level, the visual qualities of extracted watermarks are presented in Table III. These prove that the proposed method is able managed to optimize the trade-off between the robustness and imperceptibility.

TABLE III. Extracted Watermark Images

Image	Compression		Additive Noise	
	CRT	Proposed	CRT	Proposed
Baboon				
Barbara				
Boat				
Bridge				
Elaine				
Goldhill				
Jet				
Peppers				
Sailboat				
Truck				



V. CONCLUSION

This paper introduced an improvement method in watermarking using CRT and Canny operator. Instead of spreading watermark bits evenly on image area, the proposed method inserts the watermark on the edge of the image. The results show that the proposed method has significantly improved in the quality of watermarked image with the average value of 0.9995 compared to the CRT method that has average value of 0.9985. Moreover, the proposed method is able to maintain the robustness against compression and additive noise attacks. In compression and additive noise attacks the CRT has average values of 0.6618 and 0.9750 while the proposed method results in similar value i.e. 0.6616 and 0.9752. These prove that the proposed method is able to preserve the robustness and improving the imperceptibility as well.

ACKNOWLEDGMENT

The authors would like to thank to Institute of Research and Community Services (LPPM) of UDINUS for funding this study through a Science and Technology (Ipteks) Research Grants Scheme (035/A.38.04/UDN-09/III/2017).

REFERENCES

[1] N. M. Makbol and B. E. Khoo, “A new robust and secure digital image watermarking scheme based on the integer wavelet transform and singular value decomposition,” *Digit. Signal Process.*, vol. 1, no. 134, pp. 1–14, 2014.

[2] P. W. Adi and F. Z. Rahmanti, “IMAGE WATERMARKING ON LOW FREQUENCY DWT USING SINGULAR VALUE DECOMPOSITION AND DITHER QUANTIZATION,” in *Seminar Nasional Teknologi Informasi dan Komunikasi 2016 (SENTIKA 2016)*, 2016, vol. 2016, no. Sentika, pp. 460–466.

[3] C. R. S. Rao and M. V. N. K. Prasad, *Digital Watermarking Techniques in Curvelet and Ridgelet Domain*. Switzerland: Springer, 2016.

[4] S. Rao V, “A DWT-DCT-SVD Based Digital Image Watermarking Scheme Using Particle Swarm Optimization,” in *2012 IEEE Students’ Conference on Electrical, Electronics and Computer Science*, 2012, pp. 10–13.

[5] J. C. Patra, A. Karthik, and C. Bornand, “A novel CRT-based watermarking technique for authentication of multimedia contents,” *Digit. Signal Process.*, vol. 20, no. 2, pp. 442–453, 2010.

[6] J. C. Patra, J. E. Phua, and C. Bornand, “A novel DCT domain CRT-based watermarking scheme for image authentication surviving JPEG compression,” *Digit. Signal Process.*, vol. 20, no. 6, pp. 1597–1611, 2010.

[7] L. Umaroh, Y. P. Astuti, C. A. Sari, and E. H. Rachmawanto, “A Robust Image Watermarking Using Hybrid DCT and SLT,” in *2016 International Seminar on Application for Technology of Information and Communication (ISemantic)*, 2016, pp. 312–316.

[8] C. Li, Z. Zhang, Y. Wang, B. Ma, and D. Huang, “Dither modulation of significant amplitude difference for wavelet based robust watermarking,” *Neurocomputing*, vol. 166, pp. 404–415, 2015.

[9] V. Singh, R. Kumar, and A. Ojha, “Significant region based robust watermarking scheme in lifting wavelet transform domain,” *Expert Syst. Appl.*, vol. 42, no. 21, pp. 8184–8197, 2015.

[10] P. W. Adi, F. Z. Rahmanti, and N. A. Abu, “High Quality Image Steganography on Integer Haar Wavelet Transform using Modulus Function,” in *2015 International Conference on Science in Information Technology (ICSITech)*, 2015, pp. 79–84.

[11] R. Biswas and J. Sil, “An Improved Canny Edge Detection Algorithm Based on Type-2 Fuzzy Sets,” *Procedia Technol.*, vol. 4, pp. 820–824, 2012.

[12] H. Fei, S. Jinfei, Z. Zhisheng, C. Ruwen, and Z. Songqing, “Canny edge detection enhancement by general auto-regression model and bi-dimensional maximum conditional entropy,” *Optik (Stuttg).*, vol. 125, pp. 3946–3953, 2014.

[13] W. Zhang, Y. Zhao, T. P. Breckon, and L. Chen, “Noise robust image edge detection based upon the automatic anisotropic Gaussian kernels crossmark,” *Pattern Recognit.*, vol. 63, pp. 193–205, 2017.

[14] W. Stallings, *Cryptography and Network Security Principles and Practice 6th Edition*. New Jersey: Pearson, 2014.

[15] Z. Wang, A. C. Bovik, H. R. Sheikh, and E. P. Simoncelli, “Image Image quality assessment: From error visibility to structural similarity,” *IEEE Trans. Image Process.*, vol. 13, no. 4, pp. 600–612, 2004.