Journal of Information & Optimization Sciences
ISSN 0252-2667 (Print), ISSN 2169-0103 (Online)
Vol. 45 (2024), No. 4, pp. 1051–1059
DOI : 10.47974/JIOS-1627

A survey : Digital image watermarking recent trends and techniques

Himanshi Chaudhary *
Virendra P. Vishwakarma †
University School of Information, Communication & Technology
Guru Gobind Singh Indraprastha University
Sector 16-C
Dwarka
New Delhi
India

Abstract

Due to the proliferation of the web, digital content security has emerged as a substantial issue. Authentication becomes more challenging as the process of manipulating digital images becomes more streamlined. Digital watermarking provides superior protection for images compared to conventional security methods. In the modern digital age, the need for dependable image authentication methods has always been a domain of intense fascination among academicians and researchers. The transmission of sensitive information via conventional correspondence methods in the present day is susceptible to numerous breaches. Several established techniques for robustness and imperceptibility are demonstrated through the investigation and critical analysis of this study. Furthermore, an extensive overview of fundamental concepts such as the transform domain and the spatial domain is furnished. This research presents a comprehensive examination of current techniques utilized in the watermarking of digital images, as well as well-established methodologies employed in diverse fields. Therefore, this research study has the potential to be a valuable resource for scientists attempting to create watermarking techniques that are practical in nature.

Subject Classification: *Primary 68T99.*

Keywords: *Watermarking, Zero watermarking, Survey, PSNR, NC.*

1. Introduction

In this era of cameras, mobiles, CCTVs, medical Imaging, images are crucial in every domain area. They play an important role in communicating

* *E-mail:* **himanshi.c20@gmail.com (Corresponding Author)**
† *E-mail:* **virendravishwa@rediffmail.com**

whether normal or complex information well. Today's digital world of picture dissemination and manipulation makes image authenticity and integrity important. Historical records and medical diagnoses depend on images, so they must be protected from unlawful modification or replication. In a digitally connected world, photographs are essential assets that need safeguards like digital watermarking to maintain their integrity and trustworthiness.

Digital watermarking [1] is a crucial tool in protecting intellectual property rights, ensuring content authenticity, tracking, and managing content usage, document authentication, forensic analysis, and data integrity in medical imaging applications. It enables content creators to embed invisible marks into their works, deterring unauthorized use and providing legal recourse in case of infringement. Digital watermarking[2], [3], [4] also helps in tracking content usage across various platforms, detecting unauthorized redistribution, and ensuring the validity of important records and contracts. It also aids in forensic analysis and copyright enforcement in cases of digital piracy, cybercrime, or copyright infringement.

2. Background

Digital watermarking algorithms encompass two phases: embedding and extraction. In the first phase (ε), both the cover (c) and the watermark(w) are inputted, and the watermarked image(c^*) is generated. In the extraction part (ε^*), the watermark is retrieved from the watermarked cover (c^*). The mathematical representation of these phases is expressed through equations (1) and (2). The complete process is shown in Figure 1. Various metrics, discussed below, are analyzed to evaluate the performance of watermarking methods. These metrics can be applied across various domains, such as Spatial domain and Frequency domain.

$$Embedding \quad : \qquad c^* = e(c,\ w) \tag{1}$$

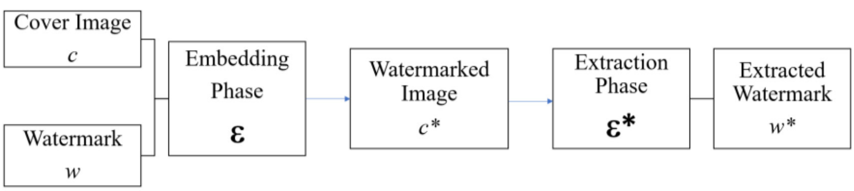

Figure 1

Digital Image Watermarking Process

$$Extraction \quad : \quad w^* = e^*(c^*) \tag{2}$$

Performance of Digital watermarking is evaluated based on four metrics:

- Robustness: Robustness states that watermarked images still have capability to produce correct watermark even after several attacks on watermarked image. There are several quantitative metrics used to check the robustness of algorithm applied such as NC and BER.
- Imperceptibility: Imperceptibility evaluates how well the watermark is incorporated in the cover so that it is visually blended in the cover image hence not detectable. Imperceptibility can also be quantified using Metrics such as PSNR and SSI.
- Security: The algorithm is termed to be secured while digital image watermarking if watermark is still authentic and intact even after many attacks attempted.
- Capacity: Capacity is defined as what size or amount of watermark can be embedded in cover, and still maintaining good robustness and Imperceptibility.

3. Exploring Watermarking Techniques

The paper[5] proposes a robust algorithm for healthcare image watermarking applying the KAZE-DCT algorithm. It addresses the poor robustness of existing algorithms against geometric attacks, ensuring secure transmission of medical images. The algorithm extracts feature vectors, applies perceptual hashing, uses chaotic mapping, and employs ZMark technology. The paper suggests future research for improved performance. The article[6] introduces a partially robust blind watermarking method for image authentication and integrity checking, demonstrating high imperceptibility, robustness when attacked, and accuracy in integrity verification. The authors[7] propose a integrated DCT-DWT-SVD based robust watermarking system for digital images. The system ensures imperceptibility, robustness, security, and payload capacity, with improved performance under various attacks. The Arnold map ensures security. The article[8] proposes a method to improve the value of metric NC of visible watermarking algorithms even when attacked. It suggests modifying the Seam Carving technique to generate different watermark patterns, which can be overlaid onto host images using any visible watermarking algorithm. The method remains visible even after attacks.

A secure retinal image management approach using deep learning[9], invertible data masking, and ZMark is proposed. The integration of U-Net and RetinaNet DL architectures results in the distinct characteristic of retina vessels segmentation and optic disk detection. ZMark codes are created utilizing message digest, spread spectrum, and seam-carving procedures. Data concealment via code division multiplexing hides the ZMark code reversibly. The proposed method validates the genuineness and completeness of the patient's identity without separating the patient from their ocular image. The algorithm results demonstrate the efficacy of the specified approach in managing retinal images. The approach preserves retinal image visual quality without compromising content, authenticates patients, and verifies image integrity. The approach also conceals extra clinical data in retinal images reversibly without impacting visual quality. High imperceptibility and integrity make the suggested approach acceptable for retinal imaging security. The proposed system is efficient and unique, as shown by a performance comparison with other cutting-edge methods. The research paper[10] presents a ZMark algorithm for geospatial vector data, focusing on resistance to projection transformation and attacks like geometrical, object addition cum deletion, and precision drop. The technique utilizes the count of vertices and the storage order as distinctive attributes, rendering it resilient against diverse attacks. The paper also analyzes the watermark index and bit, highlighting their importance in resisting geometrical, object, and precision reduction attacks. The method outperforms existing ZMark algorithms and provides valuable insights into feature invariants and algorithm effectiveness. The research paper[11] presents a ZMark algorithm for healthcare datasets using a better NasNet-Mobile CNN - DCT. The algorithm aims to improve the value of NC metric of existing healthcare data related watermarking methods. The algorithm is tested against numerous attacks, including Gaussian noise, JPEG compression, and shearing. The paper emphasizes the importance of digital watermarking technology in ensuring the non-repudiation of healthcare image information. The algorithm's practical application value and strong resistance to attacks make it a noteworthy input to the field of healthcare image security and watermarking technology.

The research[12] develops a durable ZMark strategy regarding vector maps using geometric invariances from the frequency transform and analyzes geometric statistics in vector maps' spatial domain. ZMark involves data preparation, geometric statistical information mining analysis, corner element dating information building, and efficient watermark extraction. The attack study proved the suggested system's resistance to geometric attacks, making it a feasible vector map copyright protection method. The paper [13] have discussed the design issue while performing Video watermarking. Paper[14] have shown DWT-SVD based watermarking where watermark is scrambled before embedding on Video motion. The research paper [15] suggests a ZMark technique that utilizes the Swin Transformer to enhance the protection of healthcare images within the metaverse healthcare infrastructure. The approach utilizes a method to obtain profound characteristics from images and produces binary characteristic vectors by employing the mean hashing algorithm. The logistic chaotic encryption-based experiment is employed for encrypting the watermarking image. The study findings demonstrate that the system is extremely impervious to both common and geometric attacks, therefore making it an appropriate solution for privacy protection. The report also explores the consequences of metaverse healthcare and emphasizes the necessity for enhanced data security and privacy safeguards. In the paper[16] author have discussed the LSB encryption-based methods for DICOM images. The research paper[17] presents a ZMark algorithm for protecting heath care related image confidentiality, using Resnet50-DCT. The algorithm extracts deep features from medical images, transforms them using DCT and a perceptual hash function, and embeds the original watermark into the image. The algorithm is robust, invisible, secure, and resistant to conventional and geometric attacks. It extracts watermark information with high normalized correlation coefficient values but faces challenges in balancing geometric and non-geometric attacks. The paper provides valuable insights into ZMark algorithms for healthcare image protection.

The authors [18] suggest a novel and strong ZMark technique, based on federated learning, to tackle the privacy and security issues in tele dermatological treatment. Federated learning, sparse autoencoder network, and 2D-DCT are used to separate feature vectors from dermatology medical pictures for the purpose of creating ZMark. Experiments have shown that the technique is robust against many attacks, for e.g. Gaussian noise, JPEG compression, median filtering, and geometric attacks. The proposed dermatology medical picture privacy and security strategy is more robust and applicable than ZMark schemes. The research also compares the proposed system to six representative ZMark schemes and shows that it resists conventional and geometric attacks better. The research shows potential in tele dermatology medical image security and privacy. Above discussed watermarking techniques are tabulated in Table 1 along with their respective methods used, imperceptibility or robustness evaluated, size of cover image, application area and results.

Table 1

Exploring Watermark Techniques

Ref.	Method	Factor*	Cover Image	App-lication	Results		Attacks	Remarks
					PSNR	NC		
[9]	Retinal imaging based on deep learning	I	Drive dataset (512*512)	Patient authentication	50.20 db	Na	N	Reversible data hiding, and ZMark
[10]	Feature invariants	R	four vector geographic datasets	River, highway, prefectural boundary, county boundary	Na	1	Y	Vector geographic data
[11]	Improved nasnet-mobile convolutional neural network and discrete cosine transform (dct)	R	Medical dataset from American institutes	Medical images based	10-20 db	Approx 1	Y	Encrypted watermark used
[12]	Constrained delaunay triangulation network and discrete fourier transform	R	Vector maps	Building, roads, water bodies	Na	1	Y	ZMark for vector maps
[13]	Swin transformer	R	Medical image of size 128*128	Medical images	8 -39 under common attacks; 9 - 55 under geometric attacks	Approx 1	Y	Metaverse healthcare considered
[14]	Resnet50-dct	R	Medical images	Medical images	Need to be improved	>0.5	Y	ZMark algorithm for medical image
[15]	Federated learning	R	4 dermatology medical images 128*128	Medical images	Na	~1	Y	Sparse autoencoder network- dct used

Factors*: I=Imperceptibility; R= RobustnessAttacks*: Y= Yes; N= No

4. Future Research Directions

The current state of digital image watermarking research and developments were covered in this study. This study presents the latest results derived from recent algorithms, bearing in mind that the metrics imperceptibility and robustness must be considered while using any technique. The discussed technologies and related areas on which kind of data set an algorithm can be applied. Recent developments indicate that ZMark is the new watermarking that has the potential to provide amazing outcomes. The findings demonstrate the remarkable outcomes that deep learning and machine learning-based algorithms may provide.

Conclusion

This paper includes a survey of recent technologies used to watermark digital images. First, the significance of digital image watermarking is covered in the introduction section. The process of watermarking and the measures used to assess the technique's effectiveness are covered in the next section. Following that, current methods are examined with a description of their Method, Factor, Dataset, Application, Results, Attacks, and Remarks. Ultimately, several avenues for enhancing the efficacy of watermarking methodologies are explored.

Table of Acronym

Acronym	Full Form
ZMark	Zero-Watermarking
BER	Bit Error Rate
NC	Normalized Correlation
PSNR	Peak Signal-to-Noise Ratio
SSI	Structural Similarity Index

References

[1] S. M. Mousavi, A. Naghsh, and S. A. R. Abu-Bakar, "Watermarking Techniques used in Medical Images: a Survey," *J Digit Imaging*, vol. 27, no. 6, pp. 714–729, Dec. (2014), doi: 10.1007/s10278-014-9700-5.

[2] A. Menendez-Ortiz, C. Feregrino-Uribe, R. Hasimoto-Beltran, and J. J. Garcia-Hernandez, "A Survey on Reversible Watermarking for

Multimedia Content: A Robustness Overview," *IEEE Access*, vol. 7, pp. 132662–132681 (2019), doi: 10.1109/ACCESS.2019.2940972.

[3] P. Kadian, S. M. Arora, and N. Arora, "Robust Digital Watermarking Techniques for Copyright Protection of Digital Data: A Survey," *Wireless Personal Communications*, vol. 118, no. 4. Springer, pp. 3225–3249, Jun. 01 (2021). doi: 10.1007/s11277-021-08177-w.

[4] F. Ernawan and D. Ariatmanto, "A recent survey on image watermarking using scaling factor techniques for copyright protection," *Multimed Tools Appl* (2023), doi: 10.1007/s11042-023-14447-5.

[5] Bhatnagar, Vaibhav, et al. "Descriptive analysis of COVID-19 patients in the context of India." *Journal of Interdisciplinary Mathematics* 24.3 : 489-504 (2021).

[6] A. Soualmi, A. Benhocine, and I. Midoun, "Artificial Bee Colony-Based Blind Watermarking Scheme for Color Images Alter Detection Using BRISK Features and DCT," *Arab J Sci Eng* (2023), doi: 10.1007/s13369-023-07958-8.

[7] M. Begum, J. Ferdush, and M. S. Uddin, "A Hybrid robust watermarking system based on discrete cosine transform, discrete wavelet transform, and singular value decomposition," *Journal of King Saud University - Computer and Information Sciences*, vol. 34, no. 8, pp. 5856–5867, Sep. (2022), doi: 10.1016/j.jksuci.2021.07.012.

[8] E. Fragoso-Navarro, K. Rangel-Espinoza, M. Nakano-Miyatake, M. Cedillo-Hernandez, and H. Perez-Meana, "Seam Carving based visible watermarking robust to removal attacks," *Journal of King Saud University - Computer and Information Sciences*, vol. 34, no. 7, pp. 4499–4513, Jul. (2022), doi: 10.1016/j.jksuci.2021.03.010.

[9] Z. Garcia-Nonoal, D. Mata-Mendoza, M. Cedillo-Hernandez, and M. Nakano-Miyatake, "Secure management of retinal imaging based on deep learning, zero-watermarking and reversible data hiding," *Visual Computer*, vol. 40, no. 1, pp. 245–260, Jan. (2024), doi: 10.1007/s00371-023-02778-1.

[10] S. Wang, L. Zhang, Q. Zhang, and Y. Li, "A zero-watermarking algorithm for vector geographic data based on feature invariants," *Earth Sci Inform*, vol. 16, no. 1, pp. 1073–1089, Mar. (2023), doi: 10.1007/s12145-022-00886-5.

[11] F. Dong, J. Li, U. A. Bhatti, J. Liu, Y. W. Chen, and D. Li, "Robust Zero Watermarking Algorithm for Medical Images Based on Improved

NasNet-Mobile and DCT," *Electronics (Switzerland)*, vol. 12, no. 16, Aug. (2023), doi: 10.3390/electronics12163444.

[12] X. Xi, Y. Hua, Y. Chen, and Q. Zhu, "Zero-Watermarking for Vector Maps Combining Spatial and Frequency Domain Based on Constrained Delaunay Triangulation Network and Discrete Fourier Transform," *Entropy*, vol. 25, no. 4, Apr. (2023), doi: 10.3390/e25040682.

[13] A. Saini *et al.*, "© Systematic comparison of digital video watermarking aspects with techniques and algorithm designing issue," *Journal of Discrete Mathematical Sciences and Cryptography*, pp. 1–12 (2024), doi: 10.47974/JDMSC-1646.

[14] P. Saxena and S. Kumar, "Robust video watermarking algorithm based on motion frames and encryption," *Journal of Discrete Mathematical Sciences and Cryptography*, vol. 26, no. 5, pp. 1327–1339 (2023), doi: 10.47974/JDMSC-1748.

[15] B. Han, H. Wang, D. Qiao, J. Xu, and T. Yan, "Application of Zero-Watermarking Scheme Based on Swin Transformer for Securing the Metaverse Healthcare Data," *IEEE J Biomed Health Inform* (2023), doi: 10.1109/JBHI.2023.3257340.

[16] M. K. Gupta *et al.*, "Detection and localization for watermarking technique using LSB encryption for DICOM Image," *Journal of Discrete Mathematical Sciences and Cryptography*, vol. 25, no. 1, pp. 193–204 (2022), doi: 10.1080/09720529.2021.2009193.

[17] M. Sheng, J. Li, U. A. Bhatti, J. Liu, M. Huang, and Y. W. Chen, "Zero Watermarking Algorithm for Medical Image Based on Resnet50-DCT," *Computers, Materials and Continua*, vol. 75, no. 1, pp. 293–309 (2023), doi: 10.32604/cmc.2023.036438.

[18] B. Han, R. H. Jhaveri, H. Wang, D. Qiao, and J. Du, "Application of Robust Zero-Watermarking Scheme Based on Federated Learning for Securing the Healthcare Data," *IEEE J Biomed Health Inform*, vol. 27, no. 2, pp. 804–813, Feb. (2023), doi: 10.1109/JBHI.2021.3123936.