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Comparative Analysis on Text Watermarking Techniques: Literature Review

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ABSTRACT

One of the common vast practices used for text authentication and ownership verification nowadays is through an information-hiding technique known as watermarking, which dates back to the 1990s. This paper investigates digital watermarking and its techniques that primarily focus on text watermarking. At the same time, it also tries to give a distinctive taxonomy in dealing with watermarking based on each technique. Two types of watermarking taxonomy were discussed, that includes of the type technique and attack. Techniques of text watermarking can then be further separated into three categories: embedding, approaches, and extraction. The approaches of text watermarking can be split into four categories: structure or format-based methods, text-image-based, zero-text watermarking, and linguistics ways. Ways belonging to each category were studied, and comparisons between each way are introduced by highlighting the findings. This paper also confirmed that there are principal requirements that require to be further explored and taken into account in the design of future watermarking systems, which are imperceptibility, capacity, security, and robustness.

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1. Introduction

As the Internet and information technology have grown quickly, the problem of proving the digital text documents ownership has become a subject of concern in the modern day. Technically, digital text security become a hot issue because of the easy access, an illegal copies and redistribution through the internet [1]–[3]. The utilize of watermarking is crucial in solving such issues. Text is the most common type of data transferred over the internet. As

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a result, text protection through a variety of means has become essential, and textual watermarking has drawn more attention from researchers as a solution. Cryptography is an efficient way of data security.

A watermark is a signature signal that is embedded into a digital host for a variety of purposes, such as document authenticity checks, ownership verification, identity checking. Watermarking can be applied to all text audio, video, and image content [4]. Although digital watermarking has been around since 1979, it was not given the proper acknowledgment until 1990, and it wasn't fully implemented until 1998. Even though his innovation cannot be ascribed to a specific person, it is nevertheless crucial today [2].

In watermarking, the embedding process generates a watermarked file by embed the watermark information in the host, which may also be encrypted using a secret key. The resultant file is the watermarked file, which has the same type as the host [2]. Fig. 1 shows the general watermarking model.

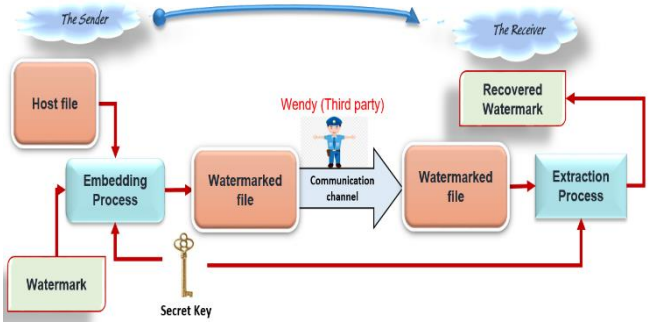

Fig. 1. General watermarking model

Meanwhile, the extraction process retrievals information (watermark) from a watermarked file. The watermarked file is a combination of the host signal into which a watermark has been embedded. The embedded watermark can be retrieved by using the host file and decoding key (if one was used). In some cases, the host file may not be required to extract the embedded watermark. Therefore, the watermark is only accessible to a receiver who processes the decoding secret key. Though, the process of selecting a host file is of a sensitive nature due to this contributes to the protection of the embedded watermark [5].

The remainder of this article is organized as follows: In Section 2, the taxonomy of text watermarking is provided. Section 3 describes the evaluation criteria. Section 4 provides a review of pertinent text watermarking studies. In Section 5 of this article, the main issues with the various methods mentioned in the literature are discussed. Include some suggestions for additional research in Section 6. Section 7 concludes by drawing conclusions.

2. TEXT WATERMARKING TAXONOMY

Alkhafaji et al. developed a taxonomy of text watermarking with two major classes [2]:

2.1 Text Watermarking Techniques

The following are three categories of ordered text watermarking technique, according to Kamaruddin et al. [6].

a. Embedding process-based: Logical and physical embedding are the two categories of embedding techniques. They specify whether the watermark is genuinely incised into the text or is only retained conceptually.

b. Approaches-based: There are four different types of watermarking techniques: structural, image, zero-watermarking and linguistic,. Although there are four methods, each one may employ a different embedding mechanism, such as logical or physical embedding. The evaluation performance of any watermarking approach, in general, is controlled by four primary requirements which are imperceptibility, capacity, security, and robustness.

c. Extraction process-based: Based on the process of extracting the watermark, the three categories of blind, semi-blind, and non-blind watermarking techniques may be established. Blind watermarking is the process of obtaining a watermark from data without needing the cover or original data [7].

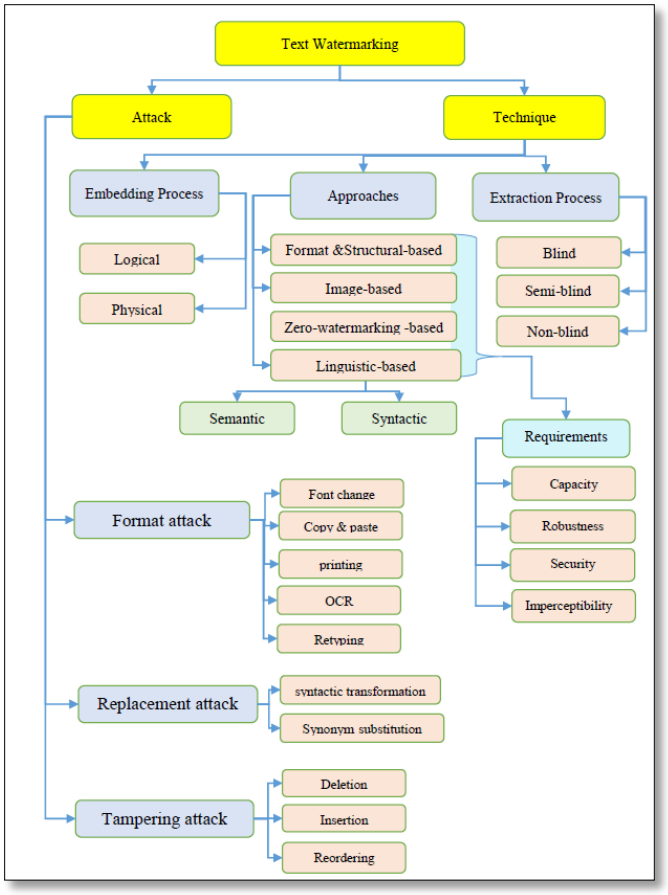

Fig.2. Text watermarking taxonomy

2.2 Text Watermarking Attacks

Attacks on text watermarks are crucial for evaluating the effectiveness and contrasting various strategies. Iqbal et al.[8], as shown in Fig. 2, described three types of attacks (assaults), such as formatting, replacement, and tampering attacks, which are frequently made against watermarked content. Consequently, a system is deemed robust if it can withstand some attacks. It is considered a semi-defense if it can only stop half of the attacks or none of them [9].

3. REQUIREMENT OF WATERMARKING SYSTEM

Any watermarking system must meet a number of conditions or criteria in order to be evaluated. The design and evaluation of the watermarking system should take into account these needs. Imperceptibility, hiding ability, security, and robustness are the four main aspects of watermarking systems that must be studied.

A. Imperceptibility

To ensure that there is no visual degradation on the watermarked medium, one may anticipate that the embedding of a watermark should be undetectable. Jaro-Winkler distance is used to give a quantitative

measure of the similarity between the host text and watermarked text through comparing two strings $(\boldsymbol{s_1}, \boldsymbol{s_2})$. The Jaro distance is computed by Eq. (1), the outcome is normalized to a number between 0 and 1, where 1 denotes complete similarity and 0 denotes no similarity [10], [11].

$$Jaro\_winkler(S, C) = Jaro_{Score} + \left(L * P * (1 - Jaro_{Score})\right) \quad (1)$$

$$Jaro\_Score = \begin{cases} 0 & m = 0 \\ \frac{1}{3}\left(\frac{m}{length(s_1)} + \frac{m}{length(s_2)} + \frac{m-t}{|m|}\right) & otherwise \end{cases}$$

Where is the number of transpositions, m is the number of matched characters, L is the length of common prefix at the beginning of the string up to maximum of 4, P is the constant scaling factor (0.1≤ P ≤0.25).

Imperceptibility and other needs like robustness, however, are in conflict. In order to better trade-off imperceptibility and robustness, the features of the host media should be taken into account when embedding the watermark.

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B. Capacity

The capacity of text watermarking methods which refers to the amount of bits that can be contained in a host signal. Due to the restricted possibilities for duplicated data, receiving a high embedding capacity rate in a text can be difficult. Therefore, the capacity of the majority of earlier text watermarking techniques has been low [12]. According to [13], capacity ratio is computed by Eq.(2) as:

$$Capacity\ ratio = \frac{Total\ No. of\ hidden\ bits}{Total\ No. of\ host\ characters} x100 \quad (2)$$

A high watermark capacity implies that the system is being used to its full capability. Even while this is a good starting point, it may affect the visibility of watermarked data. Consequently, an appropriate capacity system should have a large capacity and not interfere with watermark visibility. Various watermarking applications require a variety of powers [6].

C. Robustness

The watermarking technique should be impervious to any form of attack or malicious data processing that can distort or modify the data. During extraction, the watermark should still be discernible [14]. The robustness is measured based on the frequency with which the watermark appears in the attacked watermarked text. The watermark is regarded to have survived if it is discovered in the attacked text at least once; else, it is lost [13].

D. Security

Security demands that the payload and existence of the watermark be kept a secret. Security is maintained by the proposed technique because the embedding algorithm and watermark's existence are unknown [9].

4. RELATED WORK

This section provides examples of previous work on text watermarking with distinctive systems. The four main types of digital text watermarking approaches (see Fig. 3) are as follows:

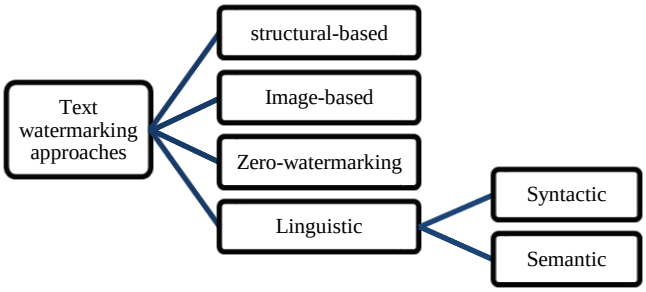

Fig. 3. Categories of text watermarking

4.1 Structural-based

Structural-based ways are accomplished through the modification of physical text arrangement to incorporate the watermark bits. These ways preserve the meaning of the host text since they do not change any individual words or sentences. For instance, Rizzo et al. [15] introduced text watermarking method that is employed the homoglyph characters and special spaces to embed watermark bits so that, some characters are replaced by similar ones with different codes for embedding 1-bit, and one special space is added between words for embedding 3-bits of watermark bits. Results indicated that while this method gave excellent invisibility, it had poor capacity, tamperable attack, visual attacks, and was limited to English.

Alotaibi and Elrefaei [13] suggested two Arabic watermarking approaches. Since pseudo-space is a small space used to separate related characters, it's added to word space to hide "0" or "1" First, Arabic dots are employed as pseudo-space. Second approach adds pseudo-space and three zero-width spaces to improve capacity; their presence signifies bit "1" and absence indicates bit "0." Comparing recommended and current approaches using variable-size text samples with varied watermark durations. Method results are powerful and imperceptible. Copying, pasting, formatting, and text tampering are blocked (84%).

Eid et al. [16] proposed the inter-word spacing and MD5 hash function generated a text fingerprint. This method proposes a blind text watermarking mechanism for copyright protection and detection of tampering in plain text. The simulation results showed that the proposed system was able to detect even the tiniest instances of content tampering and that effective copyright protection was attained thanks to the concealed key and the watermarked text's fingerprint.

Rizzo et al. [17] developed a fine-grain text watermark to secure digital assets. This technique replaces homoglyphic letters with Latin symbols and whitespace. Results revealed it adds no overhead to the original information and maintains visual indistinguishability and duration. Ahvanooey et al. [9] introduced "ANiTW" intelligent text watermarking. It used instance-based learning to hide an invisible watermark in Latin text-based data, allowing it to be extracted even if a malicious user modified the watermarked data. Experiments show that "ANiTW" is more efficient than competing approaches, especially in the short text-domain. By watermarking Quranic Arabic text, a security solution has been presented by Alkhafaji et al. [18]. Vowels are represented in structural categories by kashida. The study found an increase in capacity.

4.2 Image-based

Other studies on text watermarking produced through Image-based categories. One study utilized curved characters in Persian and Arabic. Yazdani et al. (2013) [19] created a new watermarking method for Persian documents. Curved letters like "ﭺ" ,"ﭽ" and "ﭼ" were chosen. If the watermark bit is "1," the writers adjust the letter's baseline curve; otherwise, nothing is changed. This approach is resilient against text-

image scaling and provides extra room because many letters in both languages fit this condition. Printing and scanning it can be challenging, though. Output uses a fixed font. Salem Al-maweri et al. [20] created a new digital text watermarking approach using Unicode extended characters. With PSNR values between 63.15 and 70.88 and SIM values between 99.93% and 99.97%, the algorithm is nearly imperceptible. In addition, it improves capacity by 2 bits per word and adds security. Huang et al. [21] offer a high-capacity text picture watermarking method as a printing and scanning protection. To encode watermark information consisting of many bits for a single character, a quadratic quantization function is described. This function examines the printer's resolution and its effect on the scan invariant. The QR code served as the watermark. According to the experiments, the provided text watermarking approach is resistant to print scanning and scaling, has a large capacity, and produces attractive aesthetic effects. Alotaibi and Elrefaei [22] proposed approach using DCT and IWT to watermark text-images (DCT). The hybrid approach is IWT-imperceptible and robust to DCT attacks. Using lower transform coefficients improves resilience while remaining imperceptible. DCT coefficients are 9, 16, 25, or 36. Different conclusions, but both strong and imperceptible. Add coefficients to enhance capacity. IWT-DCT stops more attacks, especially noise attacks, than older methods. It is less obvious.

4.3 Zero-watermarking-based

A few scholars focused on zero-watermark classifications. Saba et al. [23] introduced zero-based watermarking for document authentication and tamper detection. Using ECL to generate watermarks makes them brittle. ECL maintains the original document's content and transitions between characters while zero-watermarking English text. The suggested watermarking approach is evaluated using deletion, insertion, and reordering attacks. Comparing the fairness of zero-based watermarking. The recommended procedure yields better outcomes. Zhu et al. [24] suggested a text zero-watermarking technique based on Chinese letters and phonetic alphabets. The suggested method assesses text material using Chinese phonetic alphabets, extracts features, and analyzes it using a threshold interval. After a chaotic transition, the technique combines textual features with encoded watermarking information in Chinese text. Watermarking can prevent tampering up to 0.1% of the time, demonstrating its robustness and tolerance for aggressive conduct.

Khadim et al. [25] introduced a zero-text watermarking solution for PDF files. The secret information was stored using the document's objects and properties. This strategy is robust when used to format digital content. The watermark data can't be changed or deleted because it's in the document's objects or properties. Hilal et al. [26] established RETWNLPA, an intelligent hybrid technique for detecting tampering and authenticating English text. Combining zero watermark and Markov model. The order of word method for text analysis. The watermark is added onto the original English text without affecting the content. After the text is sent, the embedded watermark is used to verify for adjustments to the received English text and ensure content integrity.

4.4 Lingusitic-based

Kaur and Bhambri [27] suggested a vowel- and article-based algorithm. Embedding a watermark uses a smaller portion. The embedding approach used vowels and articles to create a unique author key. Experimental testing shows the efficiency of the proposed technique on text documents subjected to tempering attacks such as insertion and deletion. These findings are contrasted with recent work on text watermarking. Some linguistic information-hiding strategies use syntactic and semantic language properties to deliver secret data over the internet. Chen et al. [1] proposed a new watermarking method to discover semantic roles in a text using NLP. The algorithm doesn't change content or presentation. The watermark is resilient and can withstand watermark attacks and text format modifications. Xiang et al. [28] introduced a semantic-driven solution to relational textual databases' watermarking. It combines synonym replacement and arithmetic coding. Quantifying payload synonyms creates an unbalanced binary sequence.

Quantized binary sequence is losslessly compressed to fit more data. Gort et al. [29] labeled multi-word textual features using synonym replacement and semantic similarity analysis while addressing semantic disturbances caused by inserting the watermark. The experiments showed the capacity, robustness, and imperceptibility of watermarking. According to the research, the method is also resistant to random synonym replacement.

Table I summarizes related works on text watermarking, and illustrates what they are finding in their works. Also, table explains the group that belong to it and method that the way used.

Table 1. Related Works on Text Watermarking

Authors & Ref.	Group	Method	Finding
Rizzo et al. [15]	Structural-based	Employed the homoglyph characters and special spaces to embed the Watermark bit.	this method gave excellent invisibility, it had poor capacity, tamperable attack, visual attacks, and was limited to English.
Alotaibi and Elrefaei [13]	Structural-based	The Unicode standard uses whitespaces to create many symbols, some with differing lengths and others that are comparable.	Capacity and invisibility increased. Text manipulation is difficult ((84% tampering ratio))
Eid et al. [16]	Structural-based	Inter-word spacing and MD5 hash generated a text fingerprint.	Hidden key and watermarked text fingerprint detect even minor content changes and give copyright protection.
Rizzo et al. [17]	Structural-based	It substitutes Latin symbols and whitespace for homoglyphic characters.	It retains visual indistinguishability and length without adding material.
Ahvanooey et al. [9]	Structural-based	Instance-based learning to disguise an invisible watermark in Latin text data.	More imperceptibility, less capability.
Alkhafaji et al. [18]	Structural-based	Japanese vowels are represented by kashida	Increased capacity
Yazdani et al. [19]	Image-based	"ڎ" ,"ڍ" and "ڈ" are curved. Bit 1 was hidden by moving a pixel in the curved letter, and bit 0 was hidden by keeping the shape alone.	Resize-proof blind watermarking. Font-based Image attacks are weak.
Salem Al-maweri et al. [20]	Image-based	Embedded data using Unicode extended characters.	PSNR 63.15–70.88 and SIM 99.93–99.97% for high imperceptibility and security.
Huang et al. [21]	Image-based	It considers print-scan resolution and invariant. QR code watermarks were used.	Resistant to print scanning and scaling, large capacity, pleasing aesthetics.
Alotaibi and Elrefaei [22]	Image-based	Applied DCT and IWT (DCT).	Increase capacity. IWT-DCT stops more attacks, especially noise attacks, than older methods. It's less visible than others

Authors & Ref.	Group	Method	Finding
Saba et al. [23]	zero-text watermarking	Using ECL to generate watermarks makes them brittle.	Watermarking assaults (deletion, insertion, reordering) are 80.76, 80.36, and 88.1% accurate.
Zhu et al. [24]	zero-text watermarking	using Chinese phonetic alphabets, extracts features, and analyzes it using a threshold interval.	Its robustness and tolerance for aggressive conduct.
Khadim et al. [25]	zero-text watermarking	PDF page-object-based. The secret information was stored using the document's objects and properties.	This approach resists digital content formatting attacks. Watermark data in the document's objects or properties cannot be modified or erased.
Hilal et al. [26]	zero-text watermarking	RETWNLPA. Combining zero watermark with Markov model	English content authentication
Kaur and Bhambri [27]	linguistics	Using vowel ASCII letters and articles.	The proposed technique's efficiency against insertion and deletion attacks.
Chen et al. [1]	linguistics	NLP technology is used to identify a text's semantic roles.	Content and format are unaffected. The watermark can withstand attacks and format modifications
Xiang et al. [28]	linguistics	Natural language watermarking using synonyms and arithmetic coding.	Synonym counting creates an imbalanced binary sequence. Losslessly compressing quantized binary saves space.
Gort et al. [29]	linguistics	Marks multi-word textual properties using synonym replacement and semantic similarity	It confirmed the capability, robustness, and imperceptibility of watermarking.

5. DISCUSSION

According to this study, the main problems with text watermarking are copyright protection, secure communication, and authentication. Academic scholars have been interested in text watermarking techniques' efficacy, but there is not a formal analytical model that can take the fundamental needs into account when developing the watermarking system and assessing success. As embedding depends on four standard efficiency requirements. In Table I, the limits of the four main types of text watermarking techniques were discussed. These limitations give readers a good handle of the state-of-the-art and should perhaps aid in the development of future works.

Table I lists many text watermarking algorithms that are classified as having great invisibility in producing high-quality watermarked files. These algorithms were described by Rizzo et al. (2016) [15], Alotaibi and Elrefaei (2018) [13], Rizzo et al. (2019) [17], and Ahvanooey et al (2021) [9]. Despite their claims of offering high security. At the same time, some of them got low capacity like Rizzo et al. (2016) [15] and Ahvanooey et al (2021) [9]. While the algorithms of text watermarking have been achieved to increased capacity were presented by Huang et al. (2019) [21], Alotaibi Elrefaei (2019) [22], and

According to Table I, a variety of text watermarking techniques have been created to increase or improve the carrier's security and offer high robustness, as reported by Saba et al (2020), Zhu et al. (2016) [24] ,

Chen et al. (2016) [1] , Xiang et al. (2018) [28] , Gort et al. (2020) [29]. Meanwhile, Kaur and Bhambri [27] (2015) presented algorithm is robustness to tempering attacks such as insertion and deletion. And also Khadim et al. (2022) [25] presented algorithm robust against formatting attacks.

The results also show that strong imperceptibility and security are the key components of a text watermarking system, which are ascribed to the primary objective of watermarking applications in embedding significant amounts of information while maintaining the quality of the host and robustness.

6. CONCLUSION

This research provides an extensive review of the latest techniques in text watermarking. It also provides a taxonomy of text watermarking based on each approach. Two classifications of watermarking are presented, which are based on attacks and techniques. On the other hand, text watermarking approaches are also divided into four categories: structural-based, image-based, zero-watermarking, and linguistic. Ways belonging to each category were discussed. Moreover, comparisons between those ways and their findings are highlighted. The review evidently shows that robustness and information imperceptibility remain a hot topic in text watermarking.

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