

# Utilizing Digital Watermarking to Safeguard Image Copyrights on E-commerce Sites

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**ABSTRACT.** *E-commerce's boom offers convenience and variety to a growing online consumer base. However, a dark side exists – sellers are illegally copying and reposting product images, eroding customer trust. To prevent this, we propose leveraging modern digital watermarking, a technology that embeds hidden codes within images, making unauthorized copying easily detectable. This study dives into how digital watermarks work, analyzes their effectiveness, and explores their practical use in E-commerce.*

**Keywords:** Image copyright protection, Product image protection, Digital watermarking, Invisible watermark, Watermark embedding.

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**1. Introduction.** The internet's explosion has transformed how we live, from information access to business interaction. Every second, the World Wide Web churns out a massive amount of data – text, images, videos, audio, and more. Yet, this digital boom presents a critical challenge: safeguarding creative work. Major e-commerce platforms like Amazon, Lazada, Shopee, Alibaba, and Etsy often display duplicate product listings. This not only violates creators' rights but also confuses shoppers. Therefore, research on copyright protection for digital products is urgently needed.

Digital watermarks are a clever way to hide ownership details in digital files like videos, pictures, music, documents, and even 3D models. Unlike traditional watermarks, which are visible markings, digital watermarks are invisible and remain even after modifications. This embedded data helps track ownership and identify unauthorized use. However, the effectiveness of a watermark depends on its strength – a stronger watermark may alter the original file slightly. Notably, multiple watermarks of different types can be embedded within a single file for added security. Here are some common applications of digital watermarking:

- *Copyright Protection:* Digital watermarks can embed the copyright holder's identity directly into the digital work, like a hidden signature. This helps prevent unauthorized use by identifying the rightful owner even after modifications.
- *Enhanced Labeling:* Watermarks can go beyond just ownership. They can also include additional information, similar to annotations for images and sound. Unlike separate documents, watermarked annotations are virtually impossible to remove, making them ideal for applications like healthcare, where accurate labeling is crucial to avoid errors.
- *Tracking Distribution:* Similar to copyright protection, fingerprinting embeds unique information into a digital work. This information, like a serial number, identifies the

specific device used to create the content (e.g., a camera ID and timestamp). This is particularly useful for tracing the source of illegally distributed content, even if it's been shared multiple times. Each copy receives a unique fingerprint, allowing authorities to track its origin.

- *Data Verification:* Authentication uses digital watermarks to verify the integrity of data. Imagine a hidden seal on a document. By checking the watermark, users can confirm if the data hasn't been altered since its creation. This is crucial for ensuring the authenticity of digital documents, especially in sensitive fields like finance or legal matters.
- *Usage Restrictions:* Digital watermarks can carry information about permitted copying and playback. Imagine a watermark acting like a hidden license agreement. However, enforcing these restrictions requires collaboration from device manufacturers. For instance, DVD players could be equipped with watermark detectors to automatically prevent unauthorized copying, similar to the approach used in DVDs.
- *Broadcast Tracking:* Watermarks can also be used to track the broadcast of copyrighted material. By embedding a unique identifier within the content, authorities can pinpoint exactly when and where the work was aired, aiding in royalty collection and identifying unauthorized broadcasts.
- *Enhanced Content:* Watermarks can even store web addresses (URLs) as hidden references. Imagine a watermark acting like a tiny QR code. By embedding a short index number, viewers can be directed to a specific website containing relevant information. This allows creators to link digital content to additional resources seamlessly, enriching the user experience.

This research aims to elucidate the workings of digital watermarking and its potential application in the realm of e-commerce. It explores the evolution of digital watermarking from its earliest forms to contemporary techniques, and proposes a system that e-commerce platforms can adopt to safeguard the copyright of image owners.

**2. Related works.** This section investigates existing research on digital watermarking for images. We will delve into commonly used techniques highlighted in previous studies, analyze different watermarking schemes, and scrutinize the outcomes attained. These techniques embed hidden data, like copyright information, within a digital image without affecting its visual quality. The process involves two key steps: embedding the watermark and later extracting it.

Digital watermarks act like hidden identification tags embedded within digital content (videos, images, documents) to safeguard ownership and ensure authenticity. These watermarks, visible or invisible, can be used for copyright protection, verifying content hasn't been altered, and detecting unauthorized modifications.

The embedding process involves concealing confidential data, typically text, images, or other encoded information, within a digital image using the least significant bits (LSBs) [8]. The confidential data, which may comprise text, images, or other forms of data, undergoes encoding before being integrated into the image. The objective is to ensure that the alterations are imperceptible to human observers, maintaining the appearance of the image. Numerous techniques are employed for embedding confidential information, with one prevalent method being LSB substitution. In this approach, the LSBs of the image pixels are substituted with the bits of the confidential data [3]. Beyond LSB substitution, other techniques offer more robust hiding of confidential data. Spread spectrum methods scatter the data across many image pixels, making detection difficult. Even more advanced are transform domain methods like Discrete Cosine Transform (DCT) or Discrete

Wavelet Transform (DWT). These leverage the image's frequency information for watermark embedding, often resulting in a more robust watermark. Extracting the hidden data involves reversing the embedding process. The watermarked image is analyzed to identify and undo the changes made during embedding, revealing the confidential information. However, successful extraction requires knowledge of the specific embedding algorithm and any encryption or compression techniques used [2, 4, 7, 9].

In [11], the authors presented a novel approach to integrate durable watermarks into images. This method comprises two primary phases: embedding the watermark and extracting it. The algorithm integrates a unique transformation utilizing DWT and Fast Walsh-Hadamard Transform (FWHT) to embed the watermark into the image. Furthermore, it evaluates the PSNR (Peak Signal-to-Noise Ratio) of chosen images, serving as a quality metric post-embedding. For subsequent watermark extraction, the system correlates the retrieved watermark from the image with the original watermark across distinct frequency bands identified by the DWT. Bhavani et al. [5] investigated digital watermarking, a crucial technique for copyright protection by embedding a watermark into digital images for authentication. They proposed a hybrid algorithm that integrates various methods (image segmentation, Singular Value Decomposition (SVD), DWT, homomorphic filtering, and RSA encryption) to address diverse threats. Their research introduces a novel approach where two watermarks, derived by segmenting the original watermark with different thresholds, are embedded for enhanced security. In [6], the authors proposed a new method for embedding watermarks in color images to safeguard copyright. Utilizing two watermarking techniques and a multi-objective evolutionary algorithm, the system efficiently identifies optimal locations within each image to hide the watermarks imperceptibly. This approach ensures the watermarks remain resistant to tampering, making them difficult to remove even after image manipulation. Ahmadi et al. [1] introduced a blind dual watermarking system designed for color images. This system incorporates a robust, imperceptible watermark aimed at safeguarding copyright. Notably, the watermark is strategically embedded within the blue channel of the RGB color space. To strike a balance between the watermark's invisibility and its resilience against tampering, the process utilizes DWT, Human Visual System (HVS), and SVD techniques, in conjunction with a specialized Particle Swarm Optimization (PSO) algorithm. In their work [10], Pan et al. developed a more efficient and robust watermarking method using the Sparrow Search Algorithm (SSA). This technique combines SSA with a well-established method called DWT-SVD for embedding watermarks. The SSA algorithm helps find the best way to embed the watermark without affecting the original data and ensures it remains invisible. Tests show this method successfully embeds watermarks while using less memory and making them more resistant to tampering. Shahadi et al. [12] presented an adaptive and robust approach to protect image copyrights, with the goal of managing ownership and discouraging unauthorized image usage. The method involves transforming the image into a wavelet domain using a multi-level lifting wavelet transform. During this process, the lowest frequency band is divided into concentric rectangles globally, which enhances resistance to cropping. Within a rectangle selected by the user, pixels are designated for embedding flag bits, serving as a defense against rotational attacks. The proposed embedding procedure prioritizes coefficients of high energy as potential embedding positions, aiming to minimize overall errors and strengthen hidden data against noise and jpeg-compression attacks. Furthermore, a reversible scrambling technique is applied to a predefined area within the watermarked image to prevent unauthorized users from obtaining a high-quality watermarked image.

The majority of approaches found in the literature involve multiple stages. In this paper, we suggest harnessing contemporary digital watermarking techniques to facilitate the detection of unauthorized copying. This research delves into the mechanics of digital watermarks, assesses their efficacy, and investigates their practical application in E-commerce for safeguarding product image copyright.

**3. Safeguarding product image copyrights: Recommendations for E-commerce platforms.** Copyright infringement is a significant concern for e-commerce sellers, especially regarding product images. Competitors often steal these images from online listings, and in some cases, even replace the original seller's watermark with their own. This raises concerns for sellers on popular platforms like Shopee, Lazada, Amazon, and Alibaba.

While these platforms typically have terms of service regarding image copyright, enforcement methods are often limited. To enhance seller trust, deter image theft, and foster a secure environment for both sellers and buyers, here are some recommendations for e-commerce platforms:

**Enhancing image copyright protection terms.** E-commerce platforms face a major obstacle in protecting image copyright – their international reach. Copyright laws vary significantly from country to country. Their current approach to counterfeits primarily involves account blocking and limited compensation – a strategy easily bypassed by repeat offenders.

E-commerce platforms need a more robust approach. Instead of relying solely on individual country laws, they should reference internationally recognized agreements like the Berne Convention, TRIPS (Trade-Related Aspects of Intellectual Property Rights), and the Universal Copyright Convention. This would create a more unified front against copyright infringement.

**Automating image watermarking for enhanced copyright protection.** Beyond revising copyright terms, e-commerce platforms can take a proactive approach by implementing an automated image watermarking system. Here's how it would work: Shop owners would upload their original product images and a unique watermark during the product listing process. This watermark could also be saved in their profile settings for future use. The system would automatically embed the chosen watermark into all uploaded product images, ensuring every image is protected. Watermarked images would then be displayed on the platform's website without affecting image quality. In the event of a copyright dispute, the shop owner could contact customer support and provide relevant information. Support personnel could then extract the watermark from the disputed image to verify ownership.

By readily identifying the rightful owner through watermark extraction, e-commerce platforms can effectively combat copyright infringement. Violators can then be dealt with according to the platform's terms of service and relevant laws.

**4. Proposed framework.** Many frequency-domain algorithms use a technique called spread spectrum communication. In this approach, the signal is transmitted over a wider range of frequencies than minimally required. This ensures a good signal-to-noise ratio (SNR) in each frequency band, even when transmitting with high total power. Even if data is lost in some frequency bands, the signal can still be recovered from the remaining ones. This concept of spreading information is also applied in digital watermarking using spread spectrum techniques. Here, the watermark is embedded throughout the entire image and distributed across its frequency domain. An attacker trying to remove the watermark would need to add a significant amount of noise to the image. However, such heavy noise would also severely distort the image, making the attack futile.

One major benefit of frequency-domain watermarking is that it works well with common image compression methods, especially JPEG. This means the watermark stays hidden even if the image is compressed to save space online, which is very common today. This compatibility makes frequency-domain techniques ideal for practical internet applications where images are frequently compressed and shared.

Our visual perception excels at discerning details, yet not all details hold the same weight. Smooth surfaces tend to amplify imperfections, analogous to how a small scratch is glaringly obvious on a flat wall. Conversely, intricate textures can obscure minor flaws more effectively, akin to how clutter can camouflage imperfections on a busy desk. This phenomenon arises because essential image data in smooth regions predominantly resides in lower frequencies, while intricate textures disperse their information across higher frequencies. Consequently, our visual acuity is heightened towards detecting low-frequency noise (such as scratches on the wall) compared to high-frequency noise (like a speck of dust on the desk). Finding the right spot for a watermark involves a balancing act. Ideally, the watermark should be hidden well (stealthy) to avoid detection. Here's the challenge:

**Lower frequencies:** Embedding the watermark in lower frequencies makes it harder to remove (resistant to attacks) because modifying them would distort the image. However, the human eye is more sensitive to changes in these areas, so the watermark might become noticeable.

**Higher frequencies:** Hiding the watermark in higher frequencies makes it less visible (better stealth). But these frequencies are more susceptible to being lost during image compression or editing (less robust).

Watermarking techniques must strike a balance between two crucial factors: invisibility and resilience against attacks. To achieve this, a common approach embeds the watermark within the image's mid-frequency range. This involves subtly modifying the transformed data's coefficients using various methods. These methods encode the watermark based on the coefficients' perceptual significance (how noticeable they are to the human eye) or energy significance (how much information they carry). Any attempt to tamper with the watermarked image introduces noise to these already altered coefficients. During watermark retrieval, the original coefficients are subtracted from the received ones. This isolates the noise caused by manipulation, allowing for the estimation of the watermark from the noisy data with high accuracy. The main hurdle in blind watermark detection within the frequency domain lies in identifying the specific coefficients used for embedding. Several techniques can be employed for this purpose, including adding pseudo-random noise, quantization, or image fusion. Most algorithms consider the limitations of the Human Visual System (HVS) to ensure the watermark remains imperceptible. The goal is to strategically embed watermark information bits where they are most resistant to attacks and least noticeable to the human eye.

Based on the analysis presented above and the effectiveness of frequency domain watermark embedding techniques demonstrated in prior studies, we propose a novel framework utilizing watermarking to safeguard copyright of product images on E-commerce platforms. The framework entails two critical stages: (i) the watermark, which acts like a hidden identification code, is embedded into the image; (ii) this watermark can be retrieved later to verify ownership or copyright.

**4.1. Watermark embedding.** Numerous types of attacks can impact the various color channels of an original image with differing levels of severity. In this research, we introduce a multi-channel embedding technique designed to efficiently restore watermarks following various forms of attacks. The process of multi-channel embedding is illustrated in Fig. 1.

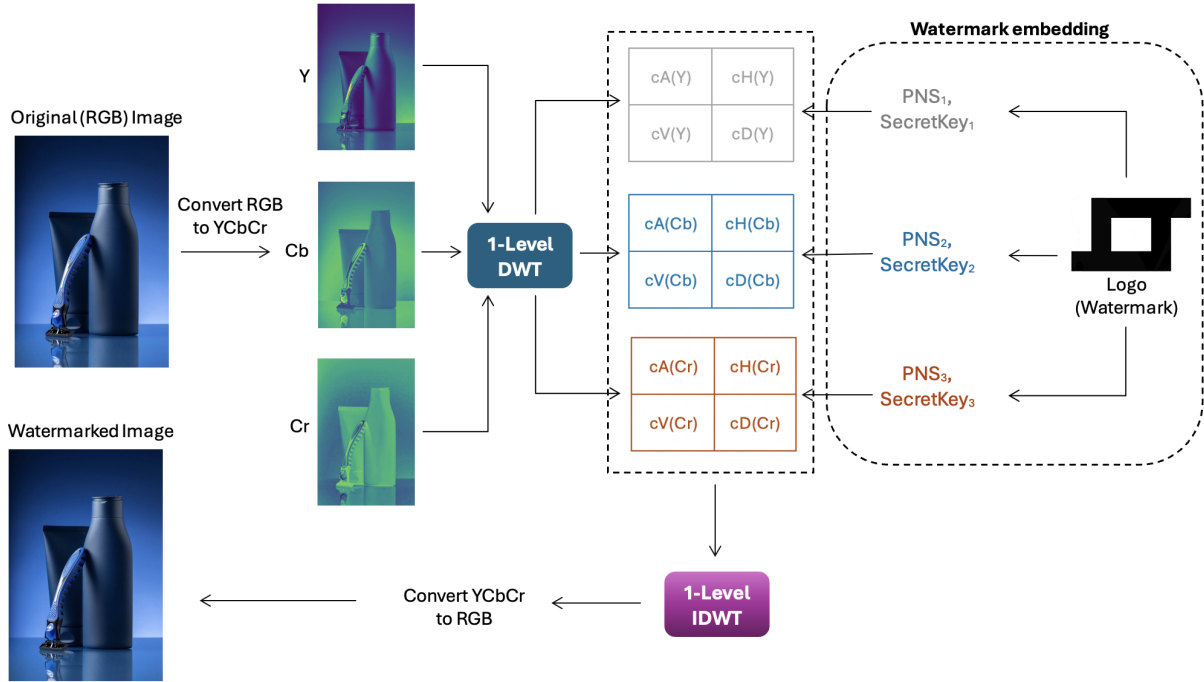


FIGURE 1. The process of multi-channel embedding.

Product images vary widely in terms of context, colors, and lighting conditions. In this study, rather than embedding the watermark directly into the RGB color image, we suggest converting the image to the YCbCr color space. This conversion allows for the separation of the image into different channels: Y (luminance or brightness) and Cb/Cr (chrominance components). This facilitates independent manipulation of light and color information, leading to a more robust watermarking strategy due to increased resistance against lighting variations and color manipulations.

The recommended watermark embedding process includes the following steps:

- *Step 1 - Image preprocessing:*
  - Load the RGB image.
  - Convert the image from RGB to YCbCr color space for improved robustness.
- *Step 2 - Watermark embedding in YCbCr domain:*
  - Apply Discrete Wavelet Transform (DWT) to each channel (Y, Cb, Cr) of the YCbCr image. This decomposes each channel into four non-overlapping sub-bands: approximation coefficients (cA) capturing the overall information, and detailed coefficients (cH, cV, cD) representing horizontal, vertical, and diagonal details, respectively.
  - To hide the watermark securely, a pseudo-random noise sequence is generated using a secret key and then embedded into each sub-band of the image.
- *Step 3 - Watermark reconstruction:*
  - Perform Inverse Discrete Wavelet Transform (IDWT) on the modified sub-bands to reconstruct the watermarked image.
- *Step 4 - Postprocessing:*
  - Transform the watermarked image from YCbCr to RGB for the final output, which appears unchanged to the naked eye.

4.2. **Watermark extraction.** Fig. 2 illustrates the watermark extraction process, which involves these steps:

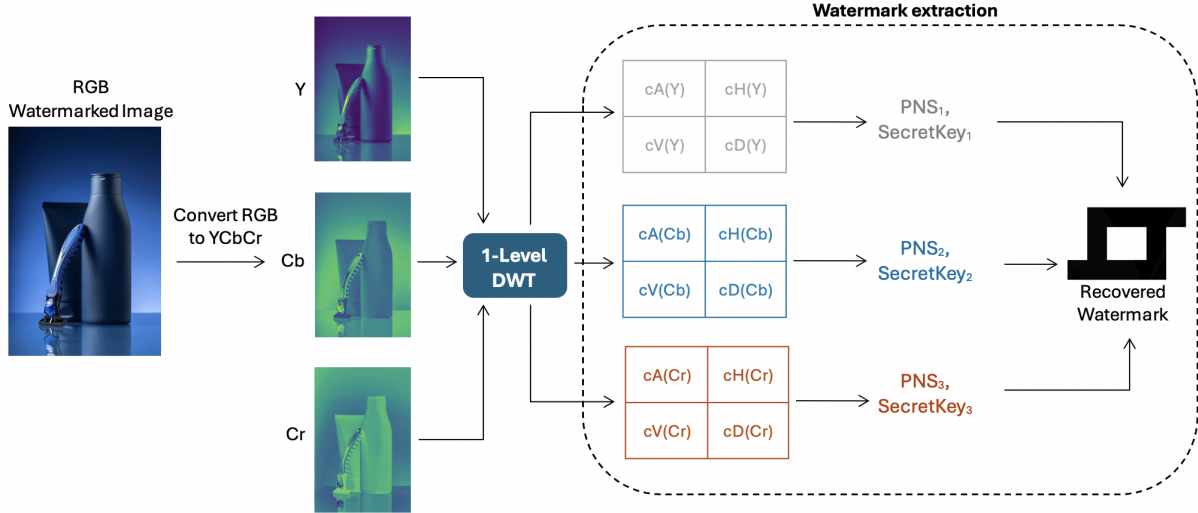


FIGURE 2. The watermark extraction process.

- *Step 1 - Image preprocessing:* Load the watermarked image and transform it into the YCbCr color space to access the embedded information.
- *Step 2 - Watermark access:* Just like embedding, Discrete Wavelet Transform (DWT) is applied to each channel (Y, Cb, Cr) of the image. This decomposes the image into the same four sub-bands (cA, cH, cV, cD) used during embedding.
- *Step 3 - Watermark retrieval:* During the embedding process, a pseudo-random noise sequence, created with a secret key, is embedded into each sub-band. In the watermark extraction phase, this same secret key is employed to distinguish the embedded watermark information from the original image data within the sub-bands. This method facilitates the retrieval of the watermark.

5. **Experimental results.** To assess the impact of watermark embedding on the original image and the fidelity of the extracted watermark, we employ several evaluation metrics:

*Mean Squared Error (MSE):* This metric quantifies the average squared difference between the original image pixels and the watermarked image pixels. Lower MSE values indicate minimal distortion caused by watermark embedding. MSE is calculated using the formula below:

$$MSE = \frac{1}{M \cdot N} \sum_{m=1}^M \sum_{n=1}^N (I(m, n) - I'(m, n))^2 \quad (1)$$

where:  $M, N$ : represent the dimensions (width and height) of the image;  $m, n$ : pixel coordinates within the image (row and column);  $I(m, n)$ : represents the intensity value of the pixel at coordinate  $(m, n)$  in the original image;  $I'(m, n)$ : represents the intensity value of the pixel at coordinate  $(m, n)$  in the watermarked image.

*Peak Signal-to-Noise Ratio (PSNR):* PSNR expresses the ratio between the maximum possible signal power (peak) and the noise power introduced by the watermark. Higher PSNR values signify a better balance between watermark strength and image quality. PSNR is mathematically defined as follows:

$$PSNR = 10 \cdot \log_{10} \left( \frac{MAX_I^2}{MSE} \right) \quad (2)$$

where:  $MAX_I$ : represents the maximum possible intensity value of a pixel in the image; MSE: mean squared error, as defined previously.

*Normalized Cross-Correlation (NCC)*: NCC measures the correlation between the original watermark and the extracted watermark. Values closer to 1 indicate a high degree of similarity, signifying successful watermark extraction. NCC is formulated as follows:

$$NCC = \frac{\sum_{m=1}^M \sum_{n=1}^N W(m, n) \times W'(m, n)}{\sqrt{\sum_{m=1}^M \sum_{n=1}^N W(m, n)^2} \times \sqrt{\sum_{m=1}^M \sum_{n=1}^N W'(m, n)^2}} \quad (3)$$

where:  $W(m, n)$  is the value of the original watermark at pixel coordinates  $(m, n)$ ;  $W'(m, n)$  is the value of the extracted watermark at the same coordinates.

In the context of e-commerce, this study explores the use of digital watermarking with brand logos. We envision a scenario where sellers seamlessly integrate their logos (as watermarks) into product images displayed on their online stores. These images can be in popular compressed formats like JPEG or PNG. Table 1 presents a list of product images used in the experiment.

TABLE 1. The list of product images used in the experiment.

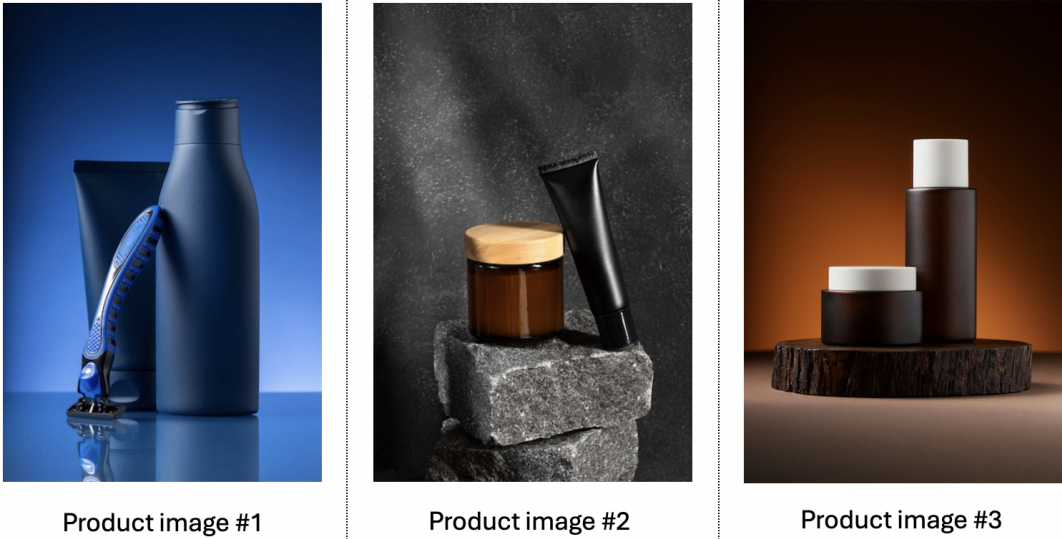


Table 2 details our experimental results. We achieved a perfect correlation ( $NCC = 1$ ) between the original watermark (brand logo) and the extracted watermark. Additionally, the PSNR values ranged from 32 dB to 33 dB, which is generally considered acceptable for image quality in this context.

It's important to acknowledge the inherent trade-off between high watermark fidelity (NCC) and minimal image quality degradation (PSNR) in watermarking. In this specific application of protecting product images on E-commerce platforms, we prioritize a high NCC value. This ensures successful extraction and clear identification of the brand logo, allowing sellers to prove ownership even if the image quality suffers slightly (lower PSNR).

To assess the effectiveness of our proposed approach, we simulated several common attack methods known to alter watermarked image distortions, including:

*Blurring*: This can distort the watermark information.













*Brightness adjustments (darker/brighter)*: These can affect the contrast and visibility of the watermark.

*Adding noise*: This involves introducing random speckles or graininess into the image. These patterns can disrupt the hidden watermark, making it harder to extract.

*Cropping*: Removing parts of the image might eliminate the watermark.



TABLE 2. Experimental results for watermark embedding without any attacks.

Original image	Watermark (Logo)	Watermarked image	Extracted watermark	PSNR (dB)	NCC
				32.06	1
				33.18	1
				32.43	1






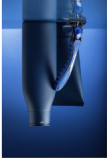

































*Rotating:* Turning the image can make it more difficult to extract the hidden watermark.

*Covering:* Obscuring specific image regions can hide the watermark.

As mentioned earlier, each type of attack impacts the Y, Cb, and Cr channels differently. We analyzed which channels were least affected by these attacks to achieve the best results, using the highest NCC as our metric. Table 3 presents the experimental results, showcasing the effectiveness of our watermark embedding approach in resisting various image manipulation techniques frequently utilized in attacks. Notably, the NCC values for the 180-degree rotation attack are lower. This vulnerability arises because image rotation disrupts the spatial relationship between the embedded watermark and the original image data. Each pixel's location is shifted, leading to misalignment and a decrease in the NCC metric. The severity of this reduction is proportional to the rotation angle, with minor rotations having a less pronounced effect compared to a 180-degree rotation. In essence, image rotation attacks pose a significant challenge in image watermarking due to their direct impact on the spatial correlation – a critical factor for successful watermark detection.

**6. Conclusions and future works.** Despite established methods like watermarking, copyright violations on e-commerce platforms remain a significant and costly problem. These violations threaten the livelihoods of creators and designers. This paper explored

TABLE 3. Experimental results for watermark embedding under common attack scenarios.

Original image	Attack methods						
	Blurring	Brightness adjustment	Adding noise	Cropping	Rotating (180°)	Covering	
							Attacked watermarked image
							Extracted watermark
	0.87	1	1	1	0.51	1	NCC
							Attacked watermarked image
							Extracted watermark
	0.91	1	1	1	0.54	1	NCC
							Attacked watermarked image
							Extracted watermark
	0.89	1	1	1	0.53	1	NCC

the application of digital watermarking to protect image copyrights on E-commerce platforms. We've also proposed strategies for these platforms to combat copyright infringement. By implementing these methods, large companies like Amazon, Alibaba, Shopee, and Lazada can significantly enhance their copyright protection efforts. This will not only uphold their own policies and simplify the process of identifying image owners during copyright disputes, but also foster a fairer environment for both creators and consumers.

Beyond the techniques explored in this paper, we envision several promising avenues for further enhancing copyright protection of product images on E-commerce platforms. These future directions involve leveraging advanced watermarking strategies:

*Content-Adaptive Watermarking:* Current methods often embed watermarks with uniform strength. A future approach could dynamically adjust watermark strength based on the image content. This would create content-adaptive watermarks that are more resilient against targeted attacks like cropping or logo removal, where attackers focus on specific image areas.

*Multi-Domain Watermarking:* Traditionally, watermarks reside in a single domain. We propose exploring multi-domain watermarking, embedding watermarks in multiple domains like spatial, frequency, and wavelet. This makes removal significantly more complex, requiring attacks to be effective across all domains.

*Deep Learning-based Watermarking:* Deep learning offers exciting possibilities for creating robust and content-adaptive watermarks. By leveraging this powerful machine learning technique, we can design watermarks that are highly resistant to removal attempts.

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