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IMPROVED WATERMARKING PERFORMANCE IN COLOR IMAGES THROUGH A HYBRID OF DWT-DCT INTEGRATION FOR COPYRIGHT PROTECTION

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Abstract

The era of big data has changed the view of data, data can now be considered as data assets. The definition of data assets is data that has rights (exploration rights, use rights, and ownership rights). Some experts believe that data assets have value at their core, the value contained can be in the form of information owned by data assets. Sharing digital data is growing every day as more people access the Internet quickly. Unauthorized individuals can easily access multimedia, such as text, images, video and audio. This research focuses on digital image watermarking to ensure security and copyright protection. This scheme uses a watermarking technique based on the hybrid of the two transformation domains (frequency domain), Discrete Wavelet Transform (DWT) and Discrete Cosine Transform (DCT). The digital image is processed into several parts by the DWT, then the watermark is embedded into one of the parts in the frequency domain using the DCT transformation, then the parts are combined again in the DWT. The experimental results show that the watermarked images achieve the highest PSNR result was 45.2719 dB, and the lowest was 43.3194 dB. an average PSNR value of 44.1254 dB, by testing ten color image datasets sourced from the SIPI-USC image database.

Keywords: Index Terms—Copyright Protection, Digital Images, Discrete Wavelet Transform, Discrete Cosine Transform, Watermarking.

Introduction

The internet is a large network that can connect all or several computer from government organizations, businesses organizations, non-business organizations, and schools from all over the world directly and quickly (Turban et al., 2007). The growth of internet users in the world, for the last twelve years from 2012 to 2023 has recently increased very rapidly. According to wearesocial.com internet users numbered 5.18 billion people and already exceeded half of the world's population by 64.6 percent in April 2023, with an annual growth rate of below 3 percent, while in the past year until April 2023 it was noted that the growth was almost close to 147 million user (Kemp, 2022). Internet users in the world are dominated by users who use mobile phones or smartphones and are also dominated by active use of social media. The world's most used social media platforms Facebook, YouTube, WhatsApp, and Instagram (Kemp, 2022).

Along with the increase in internet users who are dominated by smartphone users and are active on social media, it is undeniable that the amount of data circulating on the internet will increase rapidly. Data is a record of a concept, fact, and instructions that are

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stored in a repository and then the data can be processed automatically, so that it becomes easy to understand information (Inmon, 2005). Many have predicted an increase in the amount of data circulating on the internet, but no one can provide the amount, according to the International Data Corporation and Statista which have the same prediction, by 2025 there will be 175 ZB (Zettabytes) (Andre, 53 C.E.). The era of big data has changed the view of data, data can now be considered as data assets. The definition of data assets is data that has rights (exploration rights, use rights, and ownership rights), a collection of valuable data on the internet and can be measured and legible (Yanlin & Haijun, 2020). Some experts believe that data assets have value at their core, the value contained can be in the form of information owned by data assets (Yanlin & Haijun, 2020). There are many types of data on the internet, but this research will focus on image data or digital images. Currently, can we know with certainty the number of digital images circulating on the internet and the number of digital images created or uploaded to social media. Especially digital images, there are several billion digital images that are produced every day and shared through social media on the internet (Kwon et al., 2018). To solve this problem, researchers have developed an invisible watermark to protect intellectual property rights for ownership (Rahardi et al., 2022).

The focus of this research is digital image copyright on the internet. There are many problems that occur with digital images circulating on the internet, such as manipulation, authentication, and illegal distribution which causes the loss of valuable digital images for their owners (Ernawan et al., 2021). All internet users can share data, especially digital images. therefore, it is necessary to have a protection for digital image data in order to save the intellectual property rights of digital images (Ernawan et al., 2021).

One of the innovations that has been adapted by many industrial sectors to protect digital images is digital watermarking. The digital image is embedded by a watermark image and the watermark image can be visible or invisible (Fares et al., 2020). There are two domains that are commonly used in embedding watermarks. First, the spatial domain in this domain, the value of pixels can be easily manipulated because the complexity is very simple and second is the frequency domain is able to withstand all types of attacks because it has a more complicated complexity [10]. The most common frequency domain techniques are Discrete Cosine Transform (DCT), Discrete Wavelet Transform (DWT), Discrete Fourier Transform (DFT), Lifting Wavelet Transform (LWT), Singular Value Decomposition (SVD), and Karhunen-Loeve Transform (KLT) (Singh et al., 2021).

This paper proposes a watermarking scheme by hybrid two transforms from frequency domain, Discrete Cosine Transform (DCT) and Discrete Wavelet Transform (DWT). The purpose of hybrid the two techniques is to be used to protect copyright from digital images, because a single transformation cannot fulfill all the basic components. To fulfill all these basic components such as imperceptibility, robustness, security, and payload capacity. This research uses a hybrid transform. The first thing to do is to pre-processing the watermark image that will be embedded into a digital image with DWT technique to obtain a more stable image and have good accuracy. The second thing to do is to divide the digital image into small blocks, the processed digital image is then divided into 8x8 blocks. Then the blocks are converted into the frequency domain using the DCT technique. In the third process is the insertion of a secret message, the watermark image that will be inserted into the digital image is then converted into a bitstream and inserted into the DCT coefficients. In the fourth process, after the watermark image has been successfully inserted into the digital image, the image blocks are then converted back into spatial domains using the inverse DCT technique. In the fifth process, a digital image that already contains a secret watermark image is then converted back into a spatial domain using the inverse DWT technique. The final process is the extraction of the watermark image.

Watermark images that have been embedded in digital images can be extracted by taking the modified DCT coefficients on the digital image blocks. After that, the message is converted back to a bitstream and converted to the original message. Digital images that have been inserted with watermarks in the form of watermark images can be distributed safely via the internet. Then digital images that have been watermarked will be tested by calculating the Peak Signal to Noise Ratio (PSNR) and Mean Square Error (MSE).

Hung-Jui Ko et al. (2021) Conducted research on a robust and transparent watermarking method with a Discrete Cosine Transform (DCT) based scheme with an 8x8 block size. In general, the proposed scheme is based on the correlation of DCT coefficients between blocks, where the same position differences of two adjacent DCT blocks are exploited and the amount of coefficient modification is determined by the watermark bit. The scheme is modifying the block-based DCT coefficients. The difference in the DCT coefficients of the two blocks is calculated and modified based on the watermark bits to fit this difference to a predefined range. The first coefficient in the top left corner of the base array function is known as the direct current (DC) coefficient, while the remainder includes the alternating current (AC) coefficient. The degree of modification of the DCT coefficients depends on the DC coefficients and the median of the AC coefficients which are sorted in zig-zag order. In Experiments, there are also various attacks against watermarked images, such as cropping attacks, salt and pepper, rotation, etc. However, the results of the watermarked images before the attack were unsatisfactory. If, only the test results before the attack have a higher result, then after the attack will also get a higher value.

Jun Wang et al. (2020) Conducted research on digital image watermarking schemes, with new colors in the Discrete Cosine Transform (DCT) domain based on Just Noticeable Distortion (JND). JND is reliable in measuring the power of perception in digital image watermarking. In general, this scheme changes the digital image from RGB to YCbCr, then is divided into 2 components Y and CB. The Y component was chosen to embed the watermark and was divided into 8×8 blocks, while the CB component was used to guarantee the robustness of the scheme. Then, the new JND model combined with the proposed contrast masking and color complexity is applied to the watermarking scheme. the final stage returns YCbCr to RGB. The research results show good test results, and can withstand various attacks. however, sizes for digital images are defined.

Zear et al. (2022) Researched uses a hybrid method of Local Wavelet Transform (LWT), Discrete Cosine Transform (DCT), and Singular Value Decomposition (SVD) to insert two watermarks into a color image. The main goal is to provide high security, resistance to attack, and good-quality of reconstruction. The results of this experiment showed quite good results. However, the tests in this study did not use images commonly used in image testing.

Nguyen Chi Sy et al. (2020) Researched a new scheme based on a combine of Discrete Wavelet Transform (DWT) and Convulutional Neural Network (CNN) techniques. The way this scheme works is that digital images are processed by dwt up to 4 levels, then the low-frequency sub-band of the first level and the high-frequency sub-band of the fourth level are used as input data and output target data to train the CNN model to embed and extract watermarks. The experimental results show that this scheme has very good performance against various types of attacks on watermarked images. However, this study only tested grayscale digital images.

Narima Zermi et al. (2020) researched watermarks with a hybird approach of Discrete Wavelet Transform (DWT) and Singular Value Decomposition (SVD) for medical image protection. The digital image is modified into the frequency domain using DWT, and then the LL sub-band is modified using SVD. The watermarked image is then embedded into the SVD coefficient matrix. the watermarked image is formatted into a sequence of binary data and hashed using the MD5 function. The results show that the scheme can maintain the imperceptibility of the watermarked image. However, the scheme is limited to use for medical images only. Research with this scheme can be further developed to support various types of digital images.

Mahbuba Begum et al. [(2022)A robust watermark must have basic components such as imperceptibility, robustness, security, and payload capacity. This research aims to hybrid three transform methods between Discrete Cosine Transform (DCT), Discrete Wavelet Transform (DWT), and Singular Value Decomposition (SVD). Because a single transformation cannot fulfill all the basic components. To fulfill all these components, this research uses a hybrid transform. In the first stage, the Arnold map is used to encrypt the watermarked images. DCT is applied to the watermarked image and to the digital image followed by DWT and then SVD. In the final stage, the watermarked image is produced by inserting the watermarked image into the digital image. Research results with this scheme show high results in achieving resistance from multiple attacks. However, using a hybrid transform with all three techniques creates high complexity in terms of costs and resources. besides that, there are color limitations in digital images which are only greyscaled. This scheme can be further developed by experimenting with digital RGB images while maintaining resistance to various attacks.

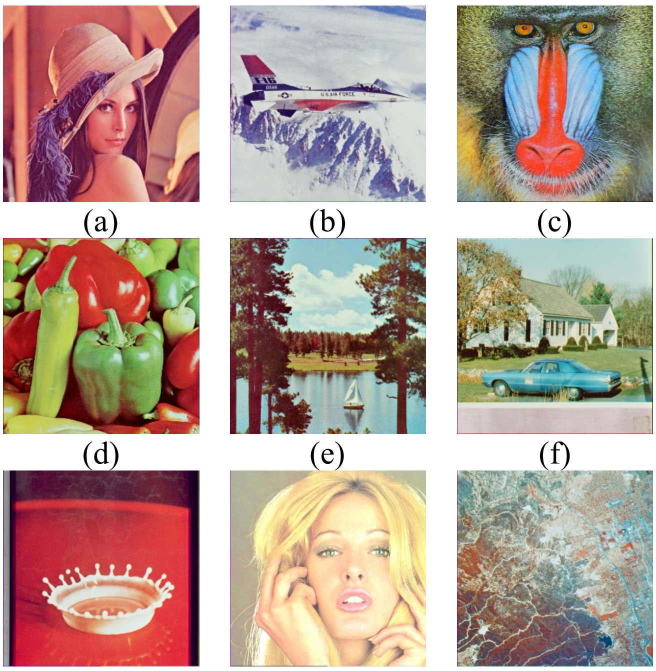
Yi Xie et al. (2020) In his research using a hybrid transform method between Discrete Wavelet Transform (DWT), Discrete Cosine Transform (DCT), and Singular Value Decomposition (SVD) with the addition of a suitable algorithm between Double-Scrambling Procedure and Pseudo Magic Square Transform. The hybrid of transforms with the Double-scrambling algorithm results in high computational complexity and requires a high-order matrix transformation. The hybrid of transformation with the double-scrambling algorithm results in high computational complexity and requires a high-order matrix transformation. Meanwhile, the Pseudo Magic Square Transform algorithm produces an easy-to-use transformation. however, it is very vulnerable to attack because its periodic characteristics are too simplistic. The results of this experiment show that each algorithm can meet the basic characteristics and depends on the purpose of its use. However, This Research on testing in this method uses only one color image dataset.

Mohamed Lebcir et al. (2020) In his research, he proposed a robust watermarking technique that does not require original information or blind watermarking for fingerprint images. This technique uses a hybrid of Dual-Tree Complex Wavelet Transform (DTCWT) and Discrete Cosine Transform (DCT) to achieve resistance to geometric attacks that may occur in fingerprint images. The results of his research show that the DTCWT-DCT hybrid is specifically designed to have resistance to geometric attacks. however, the DTCWT-DCT hybrid may involve complex calculations in the watermark insertion and extraction process. This can affect execution times and computational resource requirements, especially if the technique is to be implemented on a large scale or in real time.

Sandeep Mellimi et al. (2021) based on his research suggests a new fast and efficient image watermarking scheme based on Deep Neural Network (DNN) with Lifting Wavelet Transform (LWT). The purpose of this research is to develop a method that can insert and extract watermarks quickly and with a high degree of reliability. The insertion process is carried out by utilizing DNN capabilities in extracting important features from images. Watermarks are inserted adaptively based on the features generated by DNN, thereby ensuring the strength and high quality of watermarks. In addition, this method also has a high level of speed. The process of inserting and extracting watermarks is done quickly using parallel processing techniques from DNN. This allows the method to be used efficiently on large images in less time. Experimental results show that this method can provide a good level of watermark resistance against attacks such as compression, cropping, and filtering, while still maintaining the high visual quality of the image. and stand out in terms of speed and efficiency. However, this study only tested greyscale digital images. This research focuses on digital image watermarking to ensure security and copyright protection,

Research Methods

The digital images that will be used in this study consist of eight digital images, each digital image having a size of 512×512 pixels. These digital images were used as the dataset for this study obtained from the SIPI-USC image database. The University of Southern California (USC) provided these images for research purposes in image processing and many researchers have used these images to experiment in the field of image watermarking (Rahardi et al., 2022). The images are shown in Figure 1.



(a) (b) (c)

(d) (e) (f)

(g) (h) (i)

(j)

Figure 1. The Digital Image (Host) (a) Lena (b) Airplane (c) Baboon (d) Peppers (e) Sailboat (f) House (g) Splash (h) Tiffany (i) Woodland Hills (j) Earth From Space.

Results and Discussion

Watermark Embedding

Watermark Embedding is the process of inserting additional information called a watermark into digital content, such as images, audio, or video for identification purposes (Tao et al., 2014). Schematic of embedding a watermark image into a digital image. Each digital image depicted in Figure 1 will undergo a watermark insertion process scheme, as illustrated in Figure 2.

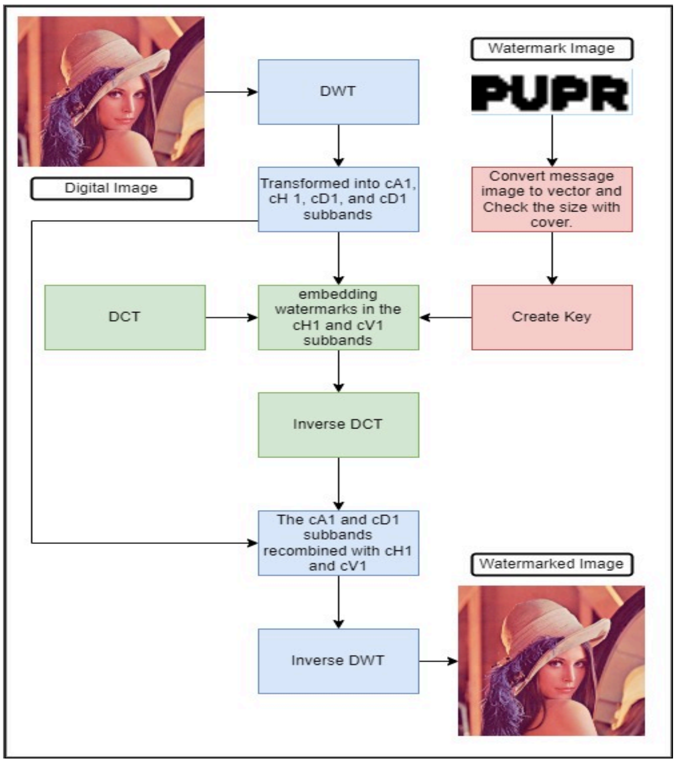


Figure 2. DWT-DCT Watermark Embedding Process.

Based on Figure 2, the process of embedding a watermark starts with the digital image being broken down into different subbands using a wavelet filter (DWT). the subbands consist of cA1 (LL), cH1 (LH), cV1 (HL), and cD1 (HH). the cA1 (Approximation) subband contains a low component (low frequency), the cH1 (Horizontal High Frequency) subband contains a horizontal high component, the cV1 (Vertical High Frequency) subband contains a vertical high component, and the cD1 (Diagonal High Frequency) subband contains the diagonal height component of the cover image.

Furthermore, in the cH1 and cV1 subbands, the DCT process was carried out. DCT converts the blocks in the subband into DCT coefficients. The DCT coefficient describes the frequency component of the blocks. The watermark image is stored in a black and white binary image with a size of 64×64 pixels and the watermark image itself is taken from the logo of the Indonesian Ministry of Public Works and Public Housing.

After that, the message to be inserted is prepared. This message is then inserted into the cH1 and cV1 subband blocks. This process is done by modifying some DCT coefficients in these blocks using PN sequence_zero or PN sequence_one, depending on the message bits to be inserted. PN sequence_zero and PN sequence_one are pseudo-random number sequences used to secure message insertion. After all the message bits are inserted, the inversion process is carried out. First, the modified DCT coefficients are returned to spatial form using Inverse DCT in each block in the cH1 and cV1 subbands. This returns the blocks to their initial spatial domain.

Next, the unmodified cA1 (Approximation) subband was coupled to the reconstructed cH1, cV1, and cD1 subbands. Then, the Inverse DWT process is applied to the combined subbands to produce a watermarked image. This image is the initial image that has been inserted with the message. The process combines the power of DWT to separate image information in the frequency domain with the power of DCT to convert frequency information into a form of modifiable coefficients. Thus, the message can be embedded into the DCT coefficients in the cH1 and cV1 subbands, which can then be reconstructed into the resulting watermarked image.

Watermark Extraction

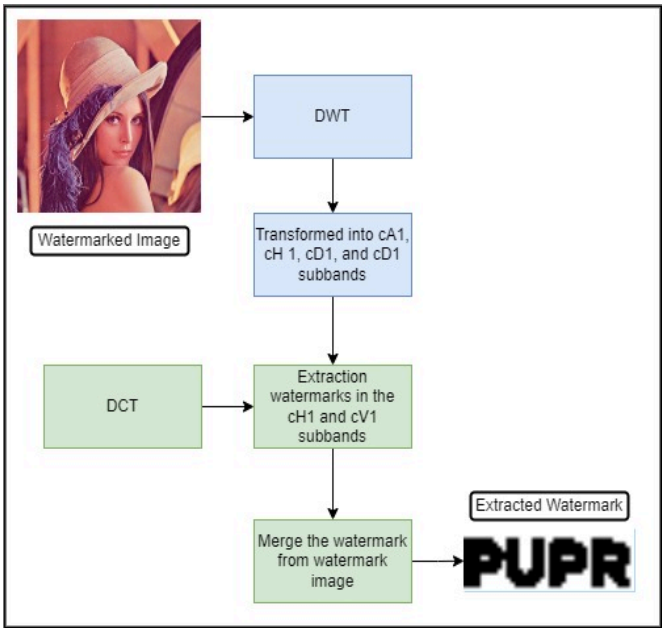


Figure 3. DWT-DCT Extraction Process

After the watermark has been successfully inserted into a digital image, the image with the watermark can be safely distributed via the internet. If the image is modified or misused by unauthorized parties, the actual owner can use the extraction process to reveal the watermark data. The extraction process is explained in Fig. 3. During the Extraction Process, the watermark extraction process should be defined as the reverse process based on the embedding process (Wazirali et al., 2021). It is used to recover original digital images and watermarks without losing any information (Meng et al., 2021). Thus the extraction process is very important because it relates to the ownership of the digital image (Le Merrer et al., 2020).

Performance Evaluation

Imperceptibility is the property of a system or technique which indicates that changes or additions to certain information cannot be easily detected by the user or recipient. In the context of watermarking, imperceptibility refers to the ability of retaining the perceptual features of the cover image after being distorted by watermarking (Ray & Roy, 2020). The less visible or invisible watermark on the digital image is an important judging criterion (Zhou et al., 2021).

To measure the imperceptibility resistance of digital images embedded with watermarks, the scheme calculates using the Peak Signal to Noise Ratio (PSNR) of digital images with watermarks. In most of the literature, PSNR is standardized as one of the metrics to calculate the evaluation of imperceptibility (Lisbeth et al., 2013; Ray & Roy, 2020). A high PSNR value proves that the differences between digital images before embedding and after embedding do not show significant differences or less distortions (Krivenko et al., 2020). The PSNR defined by:

$$MSE = \frac{1}{MN}\sum_{i=1}^{M}\sum_{j=1}^{N}\left(p(i,j) - q(i,j)\right)^2 \qquad (1)$$

$$PNSR = 10\,log_{10}\left(\frac{255^2}{MSE}\right) \qquad (2)$$

The simple explanation is that p is a digital image and q is a digital image that has been embedded with a watermark. i and j are the coordinates of the pixels. PSNR values are measured in decibels (dB). Usually, an acceptable PSNR value is at least above 30 dB (Setiadi, 2021), or better above 40 dB (Cheddad et al., 2010; Rahardi et al., 2022).

Result and Analysis

The experiment in this research is evaluated using a laptop with a 1.8 GHz octa-core Intel(R) Core (TM) i7-8565U processor, 16 GB memory, and a Windows 11 Home Single 64-bit operating system. This experiment uses MATLAB R2022a as the programming language.

After the host image is transformed by DWT into parts, the watermark image is integrated into the DCT transformation domain during the watermark embedding procedure. As a result, when compared with the digital image, the watermarked image shows undetected distortion. Figure 4 displays Splash's host image along with a watermarked version.

(a) (b) (c)

Figure 4. The Splash Image (a) The Digital Image (Host) (b) The Watermark Image (c) The Watermarked Image

As can be seen in Figure 4(c), the scheme successfully embeds the watermark into the host image. Additionally, the host image and the watermark image cannot be distinguished by the human visual system, and the watermark image cannot be seen visually from the host image. By using PSNR, the watermark image is evaluated. A higher PSNR value indicates that the watermarked image has less distortion than the original image.. A lower PSNR value, on the other hand, indicates that the watermarked image shows significant error distortion in comparison to the host image. Table I displays comparisons of imperceptibility.

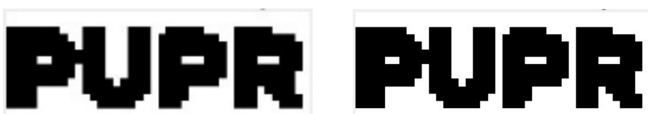
Table 1. The Imperceptibility Comparison of DWT-DCT Between Images

Image	PSNR (dB)
Lena	44.2229
Airplane	43.6164
Baboon	44.2292
Peppers	43.7612
Sailboat	44.2156
House	44.2164
Splash	44.1816
Tiffany	45.2719
Woodland Hills	44.2191
Earth From Space	43.3194
Average	44.1254

Table 2. The Imperceptibility Comparison with Related Work

Method	PSNR (dB)
Jui Ko et al. (DCT-Inter Blok Coefficient Corelation)	41.41XX
Zear et al. (LWT-DCT-SVD)	30.84XX
Xie et al. (DWT-DCT-SVD-New Scrambling)	43.2552
Proposed DWT-DCT	44.1254

Based on Table II, DWT-DCT outperforms the previous method in terms of imperceptibility under PSNR metric calculations. The PSNR value here is taken from the average value of the test results in each research conducted on the dataset. In terms of the watermark, there are also no changes to the visuals of the watermark after the process of extraction the digital image that has been embedded, shown in Fig. 5.



(a) The Watermark (b) The Watermark After Extraction

Figure 5. Comparison After Extraction

Conclusion

This paper presents a proven method for color image watermarking based on DWT-DCT for copyright protection. The DWT performs a transformation on the digital image and then each image block has been converted into a transformation domain using

DCT, this is where the embedding process occurs. The results of the experiments carried out in this research show that the watermark image achieves the highest PSNR value of 45.2719 dB in the tiffany image shown in Fig. 1(h) and the lowest in the Earth from Space image is shown in Fig. 1(j) with a PSNR value of 43.3194. With the average value of ten experiments using this method, the PSNR value is 44.1254. In the future, DWT-DCT will be tested for its resistance to various attacks and will be improved by implementing several algorithms that can improve the results of PSNR and resistance to attacks against digital image tampering.

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