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Robust Invisible Video Watermarking Using Log Gabor Mask

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ABSTRACT

The paper proposes a novel and robust watermarking technique based on the mask created by the convolution of video frame with log Gabor transform. The proposed algorithm initially creates a mask and then depending on the mask coefficients, embeds watermark in the magnitude of the FFT coefficients of the image. A watermark is embedded only in the significant coefficients determined by the filter. The concept that "filters having Gaussian transfer functions can code natural images in a better way when they are viewed on logarithmic frequency scales" is deployed in designing the watermarking algorithm. This concept along with the correlation properties of pseudo random noise patterns is explored in this paper for proposing an algorithm to embed a robust watermark in the video sequence. Robustness of the watermark is determined by the amount of attacks it could withstand. Successful extraction of watermark after application of various attacks is been possible. The performance measures PSNR, MSAD and NC are calculated and successful results are achieved.

Keywords: Gabor, Log-Gabor, Watermarking, attacks, Robust

1. INTRODUCTION

Imperceptivity is the physically powerful summit to be considered in any watermark embedding process and robustness is a research component. Imperceptivity implies that the presence of the watermark signal must be barely noticeable in the media. Robustness implies that the embedded watermark signal cannot be easily detached from the base media subsequent to application of common watermarking attacks. Significant watermark extraction is also obligatory with sturdy embedding. A robust extraction algorithm implies that even after the application of various intentional and unintentional attacks, the persistent watermark can be successfully extracted for verification by the application of the algorithm.

Literature survey reveals that watermarking is being done in spatial domain [1, 2] and Transform domain using DCT [3, 4, 5, 6, 7], DWT [8, 9, 10, 11], PCA [12], SVD [13], DT-CWT [14, 15, 16]. Review of the literature also specifies that Gabor development can afford improved signal compressions than the DCT for very low bit rates [17]. The Gabor expansion is consequently recognized as a prospective image compression tool [18-20]. Though Gabor filter is significantly used for efficient image compression, edge detection [21], feature extraction [22], texture classification [23] etc., the log Gabor filter is yet to be used for watermarking applications. This study makes successful attempt to create a mask of the log Gabor filters by convolving it with frame of the video for watermarking applications. The watermark is embedded in the magnitude of the FFT coefficients of the frame, when the mask coefficient has significant energy.

The subsequent section of the paper focuses on the concepts of the log Gabor filter followed by the proposed watermark embedding and watermark extraction algorithms. The performance measures PSNR, MSAD and NC are calculated and the results for the proposed approach are put forth in subsequent section.

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2. GABOR AND LOG GABOR FILTER

A time varying signal that is localized in both time and frequency can be represented by a function illustrated by Gabor [24]. The Gabor filter can be analysed as sinusoidal plane of certain frequency and certain orientation. The plane is then modulated by a Gaussian envelope. This time varying signal is represented by the product of the sinusoid function and the Gaussian function called as Gabor. If ω is the spatial frequency and σ is the standard deviation of the Gaussian function in x, y direction, then the Gabor function [21] created by modulating a sinusoid with Gaussian is given as

$$(x, y) = \exp\left[-\frac{x^2 + y^2}{2\sigma^2}\right] \exp\,[j\omega\,(x\,cos\,\theta + y\sin\theta)] \tag{1}$$

Gabor filters with various scales and orientations forming a filter bank are convolved with the image to get the Gabor space. This Gabor space is important for applications like optical character recognition [25], Iris recognition [26], finger print recognition [27] etc.

It is difficult to maintain a small DC component in the even-symmetric filter while constructing a Gabor function of larger bandwidth. The transfer function of an even symmetric Gabor filter in the frequency domain is the sum of two Gaussians. These two Gaussian functions are centred on the positive and negative sides of the centre frequency. The two Gaussians begin to overlap at the origin, if their standard deviations become more than one third of the centre frequency [28]. This results in a non-zero DC component.

The derivative of the Gabor filter [29] is the log Gabor filter. In [30], two major improvements on previous Gabor wavelet schemes were proposed. This paper said that the Fourier domain including the highest and lower frequencies is covered uniformly by this set of filter and hence exact reconstruction using the same filters is possible. It also stated that the highest frequency bands are covered by narrowly localized oriented filters.

The Gaussian frequency response of a Gabor filter is on a linear scale and the frequency response of the log Gabor filter is in logarithmic scale. The transfer function of a log Gabor filter on a linear scale is described by [29] as

$$G(\omega) = \exp\left(\frac{-\left(\log\left(\frac{\omega}{f0}\right)\right)2}{2\left(\log\left(\frac{k}{f0}\right)\right)2}\right) \tag{2}$$

Here $f0$ is the centre frequency of the filter and $\frac{k}{f0}$ is the bandwidth of the filter. To obtain constant shape ratio filters, the ratio of $\frac{k}{f0}$ must also be held constant for varying.

3. PROPOSED WATERMARKING ALGORITHM

The basic block diagram of watermarking is shown in Fig. 1. The algorithm accomplishes the main rationale of secure information hiding in a media for information protection issues. The binary image watermark is embedded in the video sequence and a series of attacks applied for its robustness evaluation. Following steps elaborate the details of the algorithm.

3.1. Pre-processing

The pre-processing step of proposed watermarking scheme is illustrated in Fig 1. The video sequence *Viseq = {1, 2, .. X}* is broken up into necessary frames for embedding the watermark From the size of each frame *I (M*N)*, and the size *B* of the blocks, the maximum size of the watermark to be embedded is evaluated by *Max_msg = (M*N/B^2)*. The watermark binary image *wm* is converted to a vector of size *Wmp* and padded to make it of size *Max_msg*. Fig 2 illustrates the details of the pre-processing part of the algorithm where a pre-processed video frame and the pre-processed binary watermark is given as an input to the embedding algorithm.

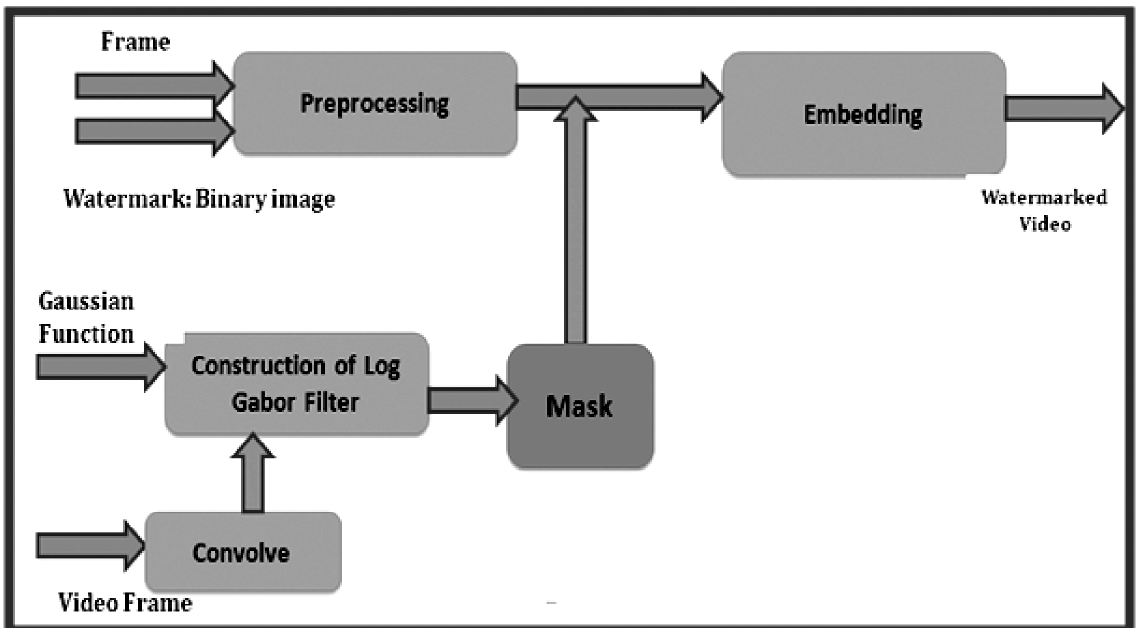


Figure 1: Diagram of Proposed Log Gabor based FFT Watermarking

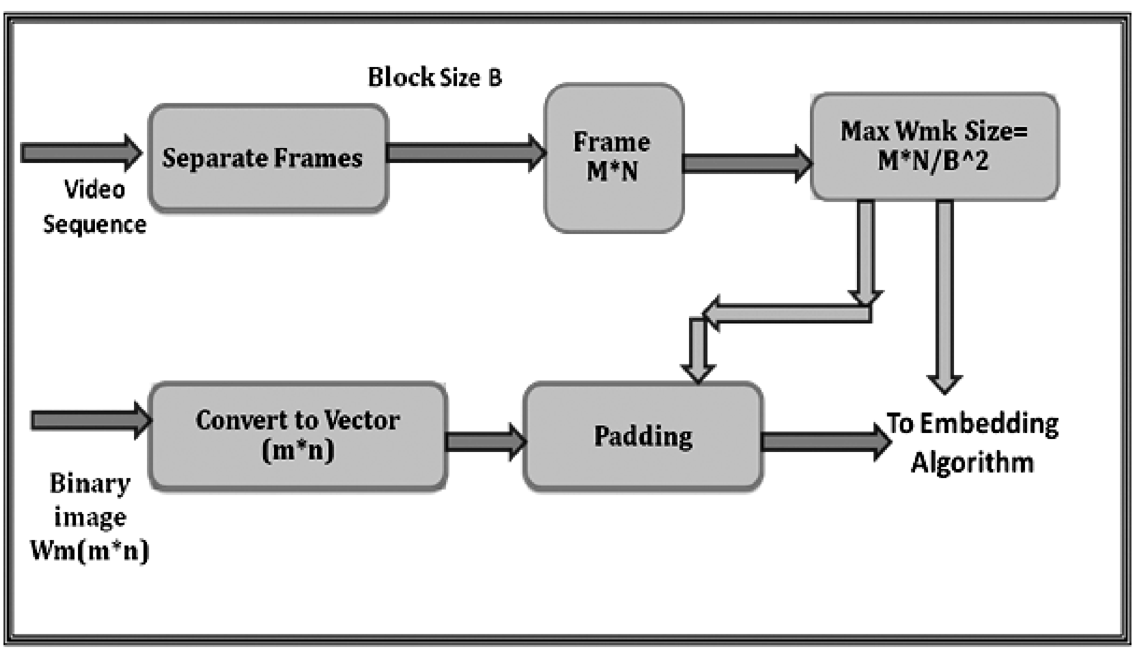


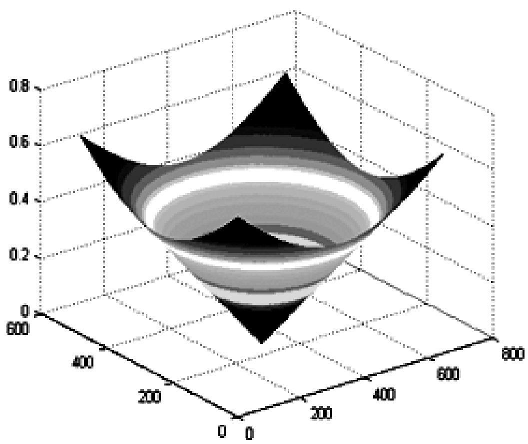
Figure 2: Pre-processing of Log Gabor based FFT Watermarking

3.2. Mask Creation using Log Gabor Filter

The mask of the video frame is created by convolving with Log Gabor filter. The filter is constructed as in [28].

- Construct Normalized radius from centre for a matrix of video frame of size *(M*N)*. Fig 3(a) shows the radius for a matrix of size of image and Fig 3(b) shows the normalized radius from the centre.
- In frequency domain the log Gabor filters $G(f, \Phi)$ are defined as $G(f, \Phi) = Gf * G\Phi$, where Gf is the radial component and $G\Phi$ is the angular component.
- The radius ω, the central frequency $f0$ and the filter bandwidth σf are the necessary parameters for the scheming of the radial component Gf and it is defined as in equation 3.

$$Gf = \exp\left[\frac{\left(-\log\left(\frac{\omega}{f0}\right)\right)^2}{2\log\left((\sigma f)^2\right)}\right] \tag{3}$$



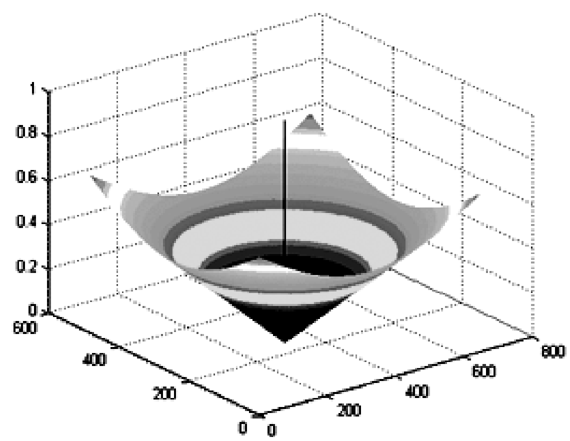
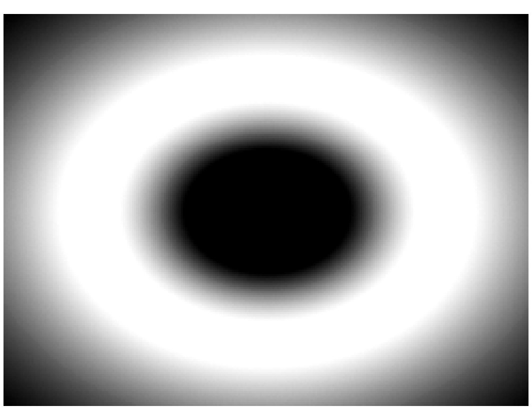


Figure 3: a) Radius of Image Matrix **b) Normalized Radius from Centre**

The image of the radial component Gf is shown in Fig 4(a) and its distribution is shown by the mesh plot in Fig 4(b).



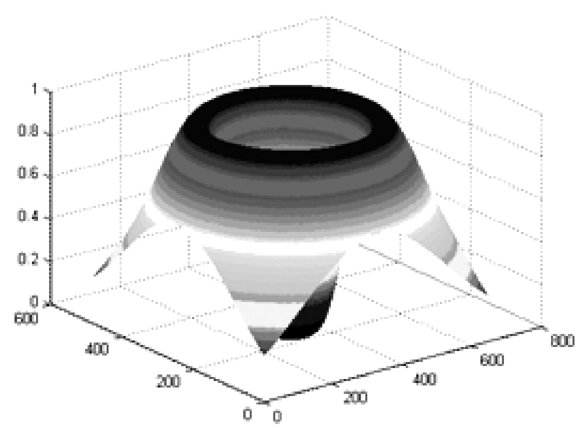


Figure 4: a) The Radial Component **b) Mesh plot of the Radial Component**

- A Gaussian with respect to polar angle around the centre having standard deviation $\Phi\sigma$ and centered at angle is the angular component $G\Phi$ controlling the orientation selectivity of the filter. The sine difference *Dsin* and the cosine difference *Dcos* are premeditated due to the angular wrap around problem in $tan\Phi$. Absolute angular distance $d\Phi$ = *abs(atan2(Dsin, Dcos))* and its mesh plot is shown in Fig 5 below.

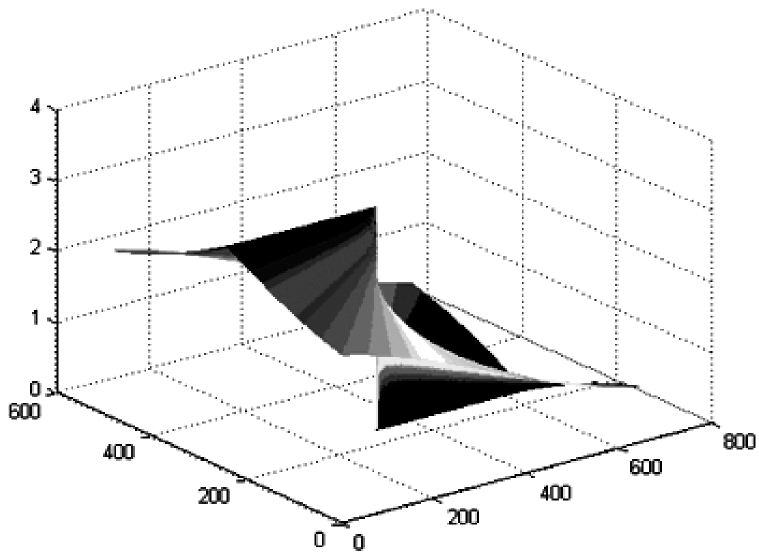


Figure 5: Absolute Angular Distance

The angular component is defined as $G\Phi = \exp\left[\frac{-d\Phi^2}{2\Phi\sigma^2}\right]$ and is illustrated in Fig 6. Fig 6(a) shows the image of the angular component and Fig 6(b) elaborates the mesh plot of its values spread in the frequency domain.

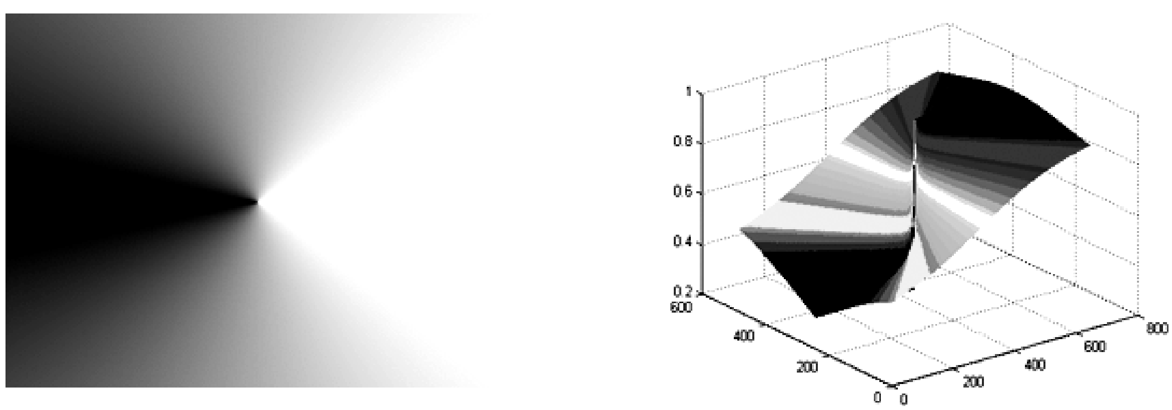


Figure 6: a) Angular Component b) Surface Plot of Angular Component

- So, the final log Gabor filter is given by

$$G(f,\Phi) = \exp\left(\frac{\left(-\log\left(\frac{\omega}{f0}\right)\right)^2}{2\log\left((\sigma f)^2\right)}\right)\exp\left(\frac{-d\Phi^2}{2\Phi\sigma^2}\right) \tag{4}$$

Fig 7(a) shows the image of the log Gabor filter and the mesh plot of the values of the log Gabor filter is indicated in Fig 7(b).

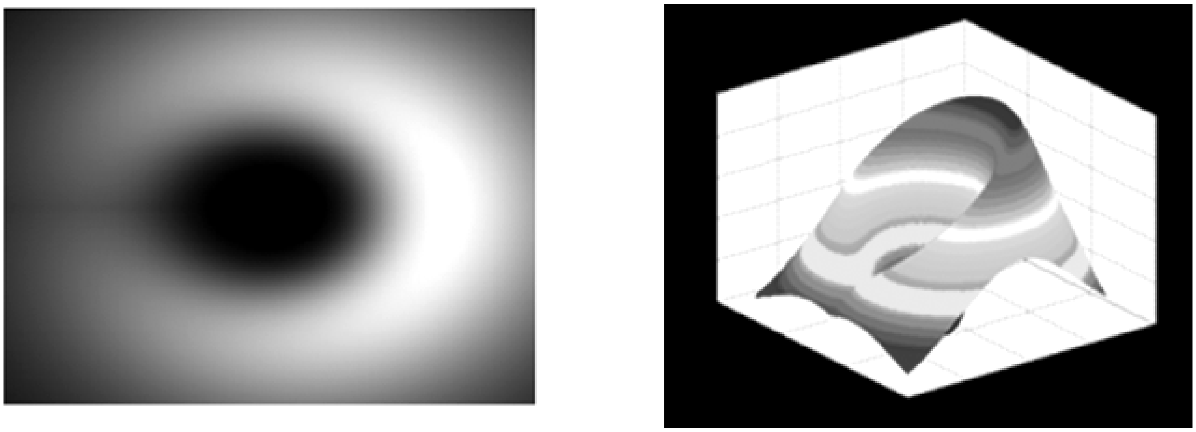


Figure 7: a) Result of Convolution of Log Gabor Filter b) Mesh Plot of Convolution of Log Gabor Filter

- The real part of inverse Fourier transform of $G(f, \Phi)$ gives the even symmetric component and the imaginary part gives the odd symmetric component of the filter.
- The filter is resized to the size of the block to be considered for embedding and flipped over horizontal axis to get the significant energy coefficients in it. This is the mask used for embedding.

3.3. Watermark Embedding

The entire embedding process is indicated in Fig 8. The elaborated steps of the algorithm are:-

- Generate two highly uncorrelated random PN sequences, pnseq0 and pnseq1 of the size of $G(f, \Phi)$. Let *I1, I2 I3... IZ* be the frames of the video of *Viseq*.
- The technique used for embedding the watermark in this algorithm is by exploring the correlation properties of additive pseudo-random noise patterns as applied to an image [31].
- Compute the FFT of *I(x,y)*.
- Each bit of *Wmp* is verified for its strength.
- $G(f, \Phi)$ for a predefined scale *Ns* and an orientation *No* is computed.

  Ns = No = 1 (for proposed implementation)
- The position where the mask created is 1, is the place of embedding the watermark. *pnseq0* is embedded if *Wmp = 0* and *pnseq1* is embedded if *Wmp = 1* using

$$P_{W(x,y)}(u,v) = \begin{cases} I_{x,y}(u,v) + K * Pnseq\ 0\ Wmp = 0\ and\ I(x,y)\ \in\ Viseq \\ I_{x,y}(u,v) + K * Pnseq\ 0\ Wmp = 1\ and\ I(x,y)\ \in\ Viseq \end{cases}$$

- Perform inverse Fourier transform to get the watermarked image and hence the watermarked video.

3.4. Watermark Extraction

The entire extraction process is elaborated in Fig.9 and the details of the extraction of the binary watermark by the proposed algorithm is as follows

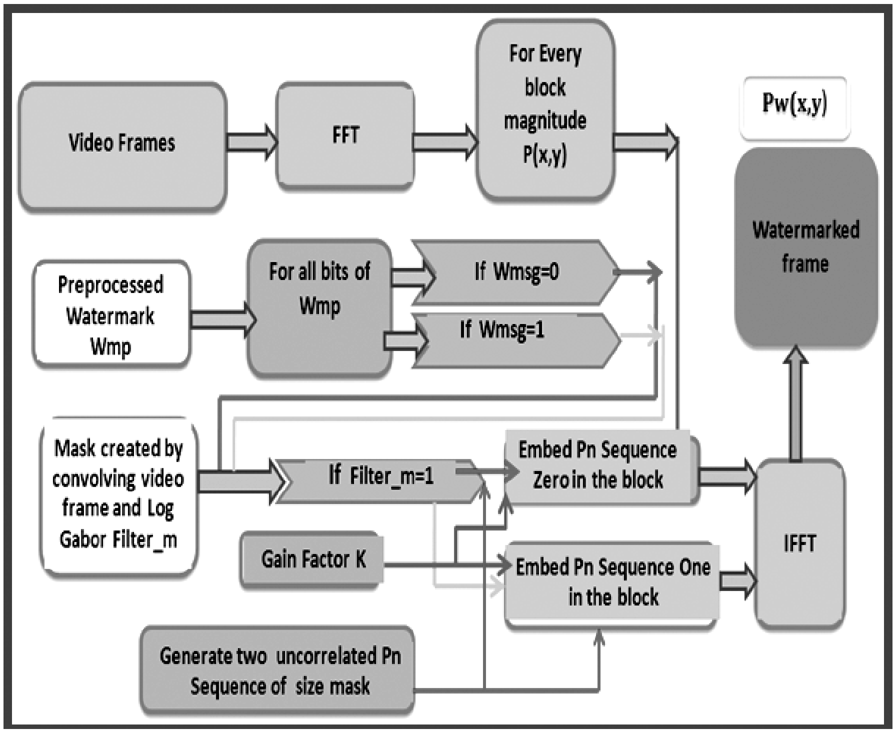


Figure 8: Proposed Log Gabor Mask based FFT Watermark Embedding

- Each bit of *Wmp* is verified for its strength.
- Convolving watermarked frame with the log Gabor filter $G(f, \Phi)$ for the same predefined scale *Ns* and an orientation *No* as that of embedding is figured out to create the mask.
- Generate two highly uncorrelated random PN sequences, *pnseq0* and *pnseq1* of the size of $G(f, \Phi)$
- Find FFT of $P_{W(x, y)}$ from a frame of the watermarked video sequence and generate the magnitude *abs_block* and angle *angle_block* for each block. Generate a new sequence from the block where the mask coefficient is one.

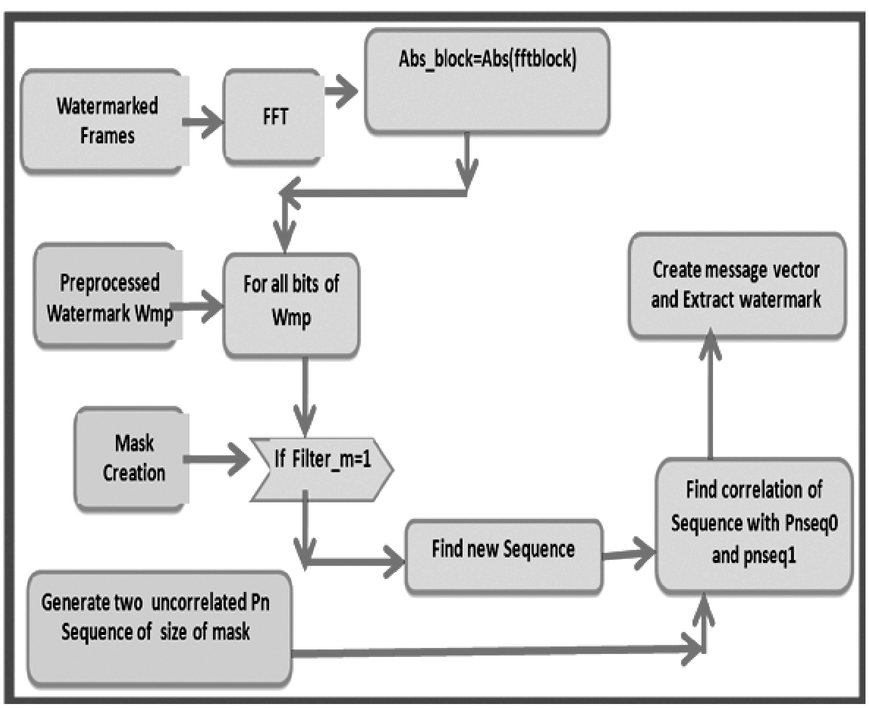


Figure 9: Proposed Log Gabor Mask based FFT Watermark Extraction

- Find the correlation matrix comparing the original PN sequence and the new created sequence to extract the watermark.

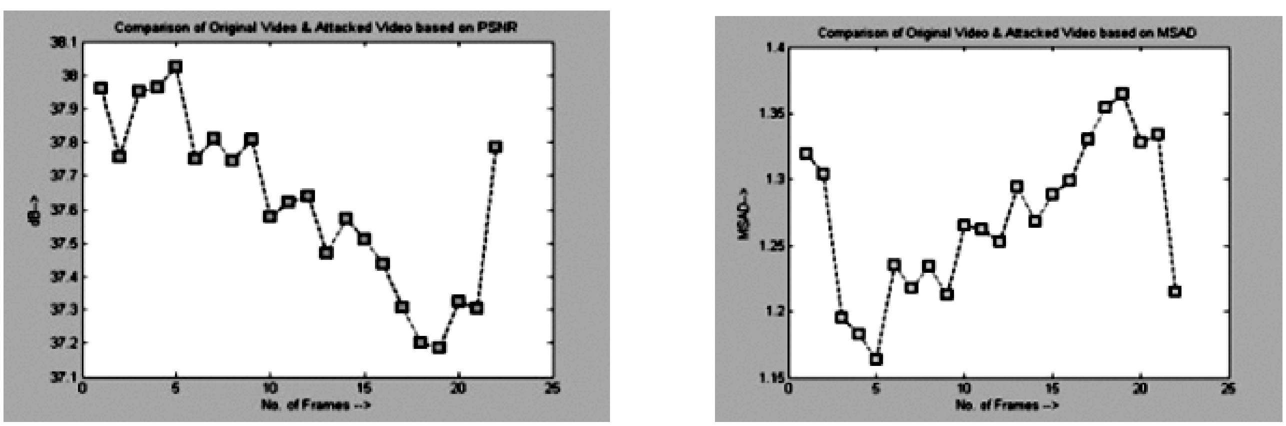
4. EXPEIMENTED RESULTS AND DISCUSSIONS

The algorithm is experimented on various parameters for its performance. The quality of the video after application of the attacks is tested by the evaluated parameters PSNR and MSAD and the robustness of the extracted watermark is tested by calculating the normalized cross correlation.

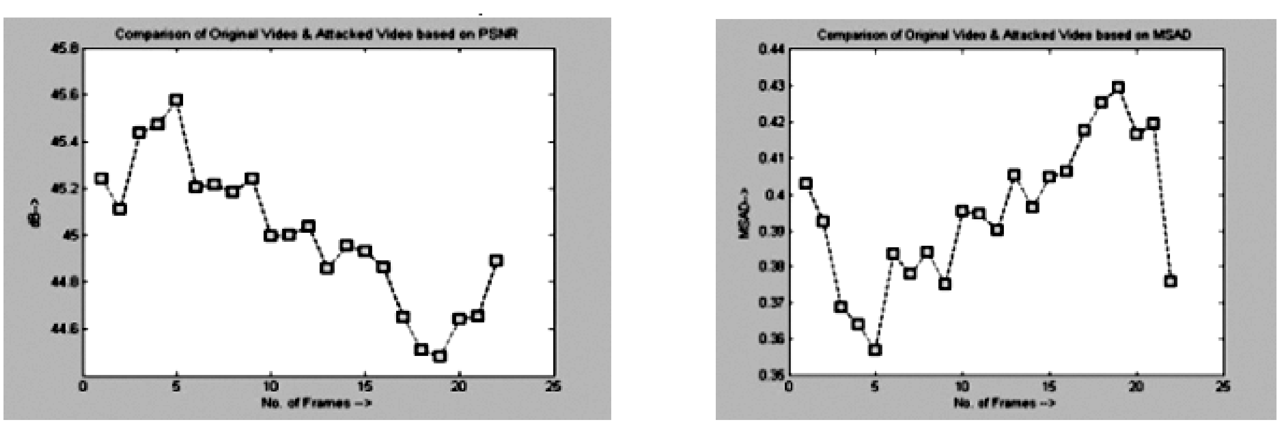
a) The quality of the video after attack: - The quality of the video after application of attacks is measured by the peak signal to noise ratio and the difference between the colour components measured by MSAD. The results of the PSNR and MSAD after application 3×3 averaging filter attacks, Gaussian filter attack, sharpening attack and swapping frames attack is illustrated in Fig 10. The PSNR and MSAD gave sufficiently acceptable results.

b) The robustness of the algorithm: Fig 11 elaborates the original frame and the watermark to be used for embedding. Attacked frames with their extracted watermarks are illustrated in Fig 12. The algorithm is able to resist the contrast stretching attack achieving a successful extraction with a normalized correlation coefficient of 0.94. The algorithm is robust to frame dropping attacks. A successful watermark is extracted after dropping single frame, 2 frames and 3 frames respectively. The robustness for the 3×3 Gaussian filters also gave good results attaining 95 % accuracy of the extracted watermark. The extraction algorithm could also withstand salt and pepper noise with a noise density in the range of 0.01 to 0.09 yielding 95 % accuracy of extracted watermark. It sustained 0.5 scaling attack and also the sampling attack.

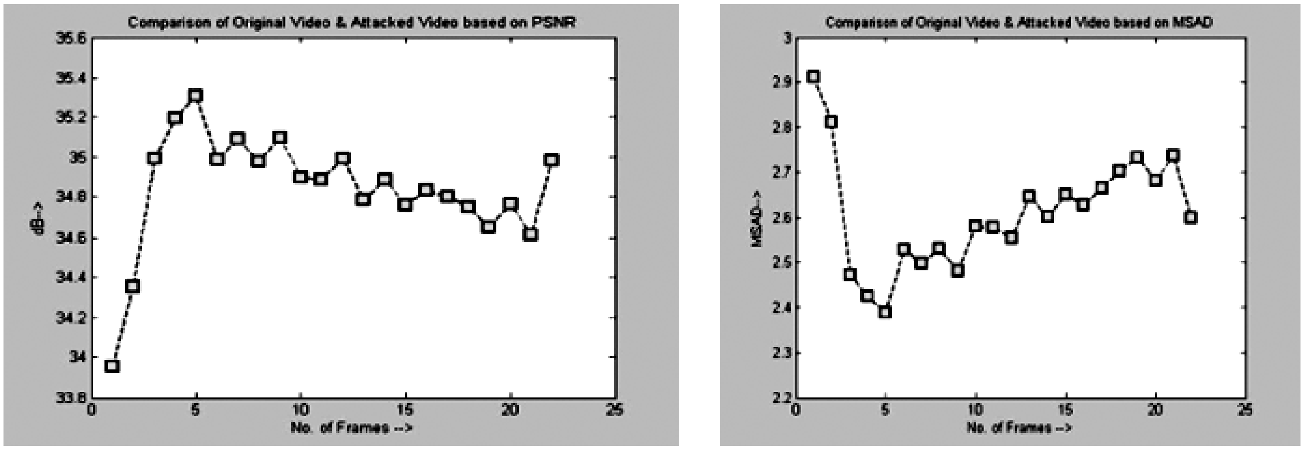
PSNR **MSAD**



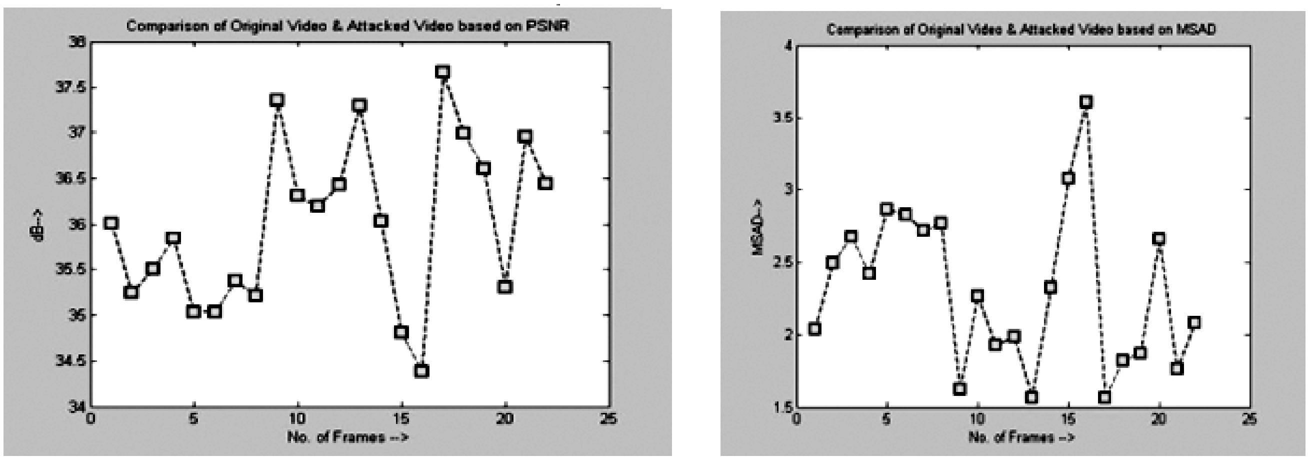
(a) Averaging Filter



(b) Gaussian Filter



(c) Sharpening



(d) Frame Swapping

Figure 10: PSNR and MSAD of Log Gabor based FFT Watermarking

Original Video Frame

Watermark

Figure 11: Original Frame and Binary Watermark for Log Gabor Filter Based FFT Watermarking

c) The NC Value using the log Gabor mask based FFT algorithm is illustrated in Fig 13. Satisfactory results are obtained and the major result is that the quality of the extracted watermark is significantly increased when a mask of the log Gabor was used as the basis for embedding the watermark.

Figure 12: Attacked Frames and Extracted Watermarks of Log Gabor Based FFT Watermarking

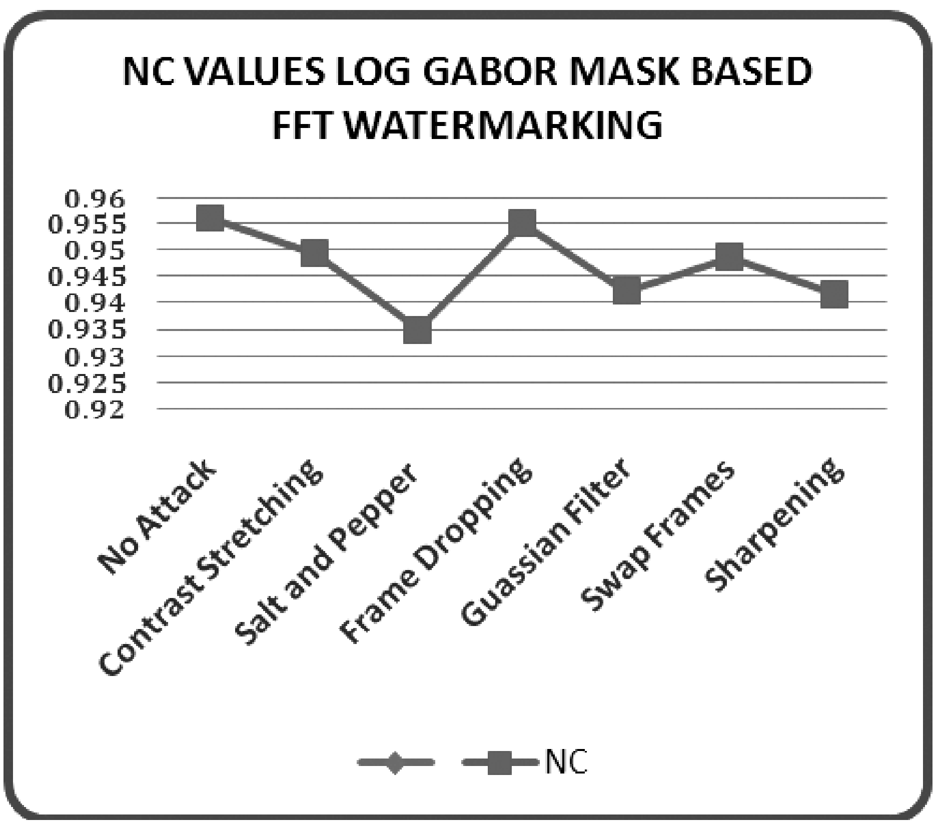


Figure 13: NC Values of Log Gabor Based FFT Watermarking

5. CONCLUSION

The watermarking algorithm based on the mask created by the convolving the log Gabor filter with the video frame is proposed. The concept of log Gabor filtering along with the exploration of the correlation properties of pseudo random noise patterns is explored to embed robust watermark in the magnitude of the FFT coefficients of a video frames. Robustness of the watermark is justified by the application of various attacks. The algorithm successfully withstands the noise, signal processing and video watermarking attacks.

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