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Video watermarking with Curvelet Transform

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Abstract*: In wireless communications, secured transmission of video has gained considerable research interest. The traditional wavelets are poor in handling curve singularities. Therefore, to handle them curvelet transforms are used. This transform exhibits minimum mean square error between the original and reconstructed image. Therefore, in this work, a watermarking is proposed with this transform using quantization index modulation. The watermark is embedded in the low resolution part of curvelet coefficients using dither quantization. To provide security, the mark is enciphered with Toral Amorphism. The algorithm is blind and the experimental results confirms that the proposed watermarking scheme offers high imperceptibility at the same time robust to attacks such as rotation, blurring due to camera motion and H.264 compression. To evaluate the performance of the watermarking scheme performance metrics Peak Signal to Noise ratio (PSNR) and Normalized Cross Correlation (NCC) are used in the work. The proposed algorithm is compared with recent works and the proposed algorithm offers high invisibility and resistance to attacks.

***Index Terms*: Curvelet transform, H.264 compression, Dither quantization, PSNR, NCC**

I. INTRODUCTION

Nowadays there is a widespread diffusion of digital video based applications such as video conferencing, video chatting, video gaming, wireless video and internet video etc. [1]. It has resulted misuse of video content by violating the copyrights of original recipients of work. To address this and to provide security to the multimedia documents, watermarking is evolved as a viable solution [2]. In video watermarking, a signature called watermark is integrated in host multimedia video to obtain watermarked video. The distortion introduced by the signature must be minimal and there is no perceptible distinction between watermarked and host video. Therefore, watermarking the video content helps to protect the rights of content owners and provide a trace of misuse in multimedia documents. Watermarking techniques are classified in to two types based on the requirement of host video for watermark recovery [3]. If the watermark recovery requires frames of watermarked video in addition to host video then it is called non-blind watermarking [4]. To extract watermark in blind method, host video is not required [3]. This section presents application of transform domain techniques in digital video watermarking. In our previous work, a phase video watermarking [2] is proposed with DFT.The advantage of this method is watermark concealed in the phase is more robust to attacks and is imperceptible. However the DFT has bottleneck of not handling point singularities [2]. Another watermarking scheme is proposed

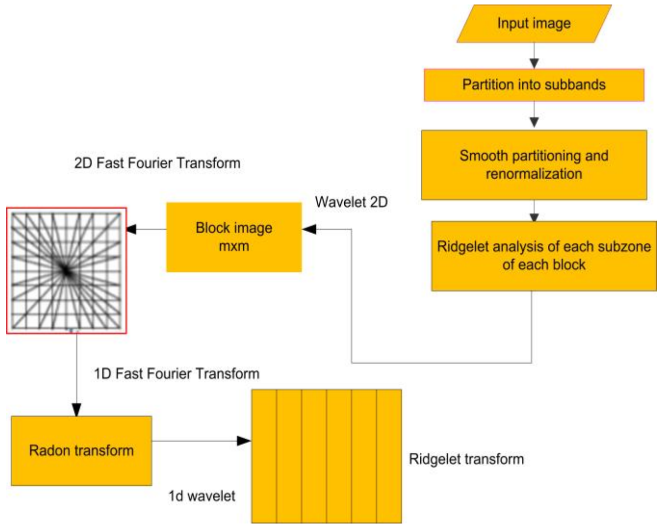

Fig 1. Steps in Curvelet transform

based on Complex Conjugate Symmetric Sequency Hadamard Transform [5].Though this watermarking scheme has an improved advantage of less hardware requirement, it is also poor in handling point or curve singularities. Another watermarking scheme is proposed by [6] based on Bi-orthogonal Wavelet Transform using Artificial Bee Colony Optimization (ABC). The optimization algorithms are generally suffered with the high computational complexity. Moreover, it cannot handle curve singularities. Due to these limitations, we proposed a watermarking using curvelet transform.

II. PRELIMINARIES

This section briefly describes the Curvelet transform as given below

A. Curvelet Transform

It is a multi-scale transform developed by Donoho and Candes [7]. The important feature of this transform is that it can pack edge information in fewer coefficients and the theoretical results show an edge to squared error 1/N requires 1/N Wavelet coefficients. On the other hand Curvelets requires only $\frac{1}{\sqrt{N}}$ coefficients [8]. . In 2-dimensional space and image is represented in spatial coordinates x, y and its corresponding frequency coordinates by F (U, V). The polar coordinates in frequency domain is represented by r= $\sqrt{U^2+V^2}$ and phase $\theta = \tan^{-1}\frac{U}{V}$.

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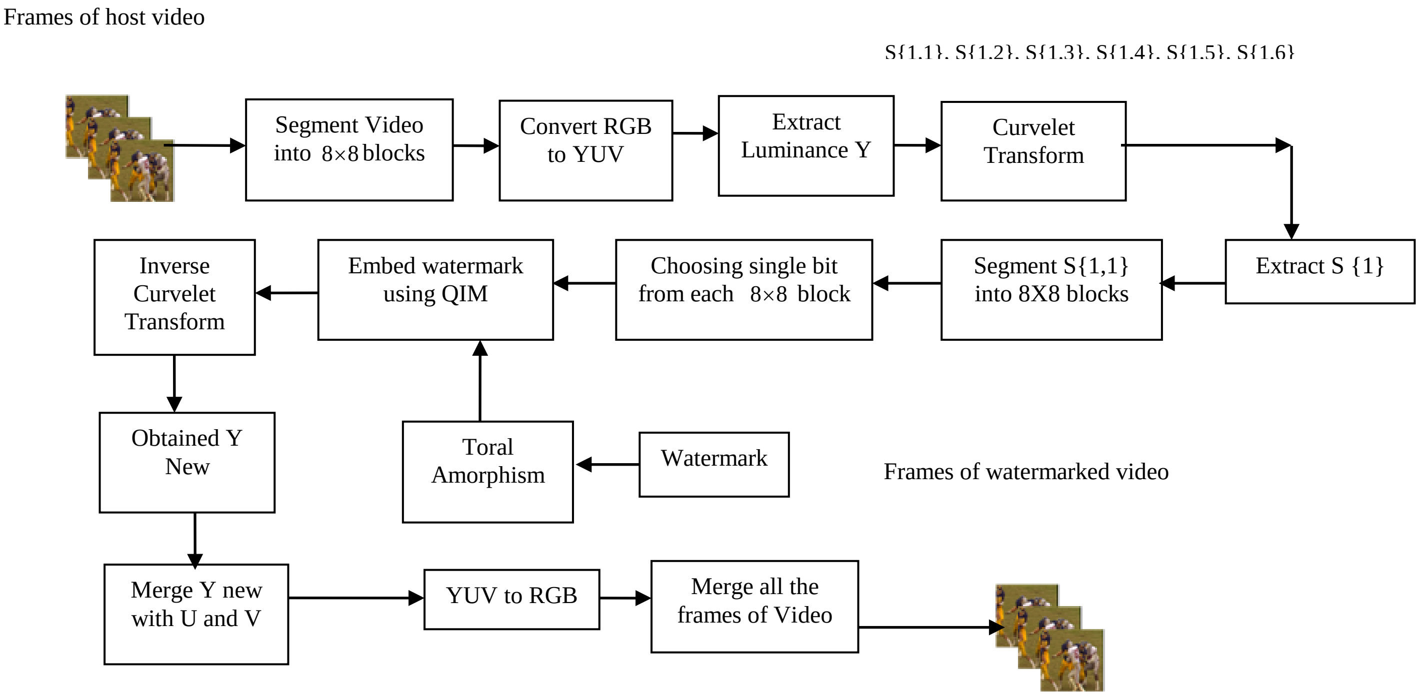

Fig.2. Watermark concealing using Curvelet transform

The image in pixel domain f(x, y) can be converted to F(U,V) by 2D Fast Fourier Transform (FFT2D). Later the grid point locations are changed to the polar coordinates F(r ,θ). After this using the interpolation, equi−distance grid points along a radial line is taken to obtain number of projections; the number of points along a radial direction corresponds to the number of shifts in the wavelet transform. Later 1D inverse FFT is applied to obtain the Radon transform. Radon transforms are mainly used in computer tomography. Afterwards, 1D DWT is applied to obtain the Ridgelet Transform [9]. The continuous Ridgelet transform provides a sparse representation of both smooth functions and of perfectly straight edges. A Ridgelet transform in 2D f(x,y) can be written as superposition of elements of the form $a^{-1/2}\varphi\left(\frac{x\cos\theta+y\sin\theta+a}{b}\right)$ where φ is a wavelet function. Here, a > 0 is a scale parameter, θ is orientation parameter and b is a location scalar parameter. The Ridgelet coefficients are obtained as

$$R_f(a,b,\theta)=\int \varphi_{a,b,\theta}\, f(x)dx \qquad (1)$$

The Inverse Radon transform for image reconstruction is given by

$$f(x)=\int_0^{2\Pi}\int_{\infty}^{-\infty}\int_0^{\infty}\varphi_{a,b,\theta}(x)\frac{da}{a^3}db \qquad (2)$$

is valid for functions which are integrable and square integrable. Radon transform of an object f is defined as collection of line integrals denoted by [10].

$$\boldsymbol{R_f(\theta,t)=\int f(x,y)(x\cos\theta+y\sin\theta-t)dxdy} \qquad (3)$$

where δ is a dirac function. The ridgelet coefficients are calculated through radon transform [11] using

$$\boldsymbol{R_f(a,b,\theta)=\int R_f(\theta,t)^{-\frac{1}{2}}\varphi\left(\frac{x\cos\theta+y\sin\theta-b}{a}\right)} \qquad (4)$$

The ridgelet transform provides optimal results for line singularities. The directional selectivity of this transform is used to capture higher dimensional discontinuities.Ridgelets are effective only to represent straight line singularities. To address this curve singularities the natural idea is to subdivide image and then apply ridgelets. The transform obtained in this way is called curvelets.

III. PROPOSED WATERMARKING SCHEME

The mean square error between the host and watermarked video is minimum in Curvelet Transform compared to the wavelets. This feature is explored in the present methodology to obtain improved invisibility. Further the watermark is concealed in approximated coefficients of the Curvelet Transform to enhance the robustness. To improve the security the watermark is preprocessed with Toral Amorphism [12].

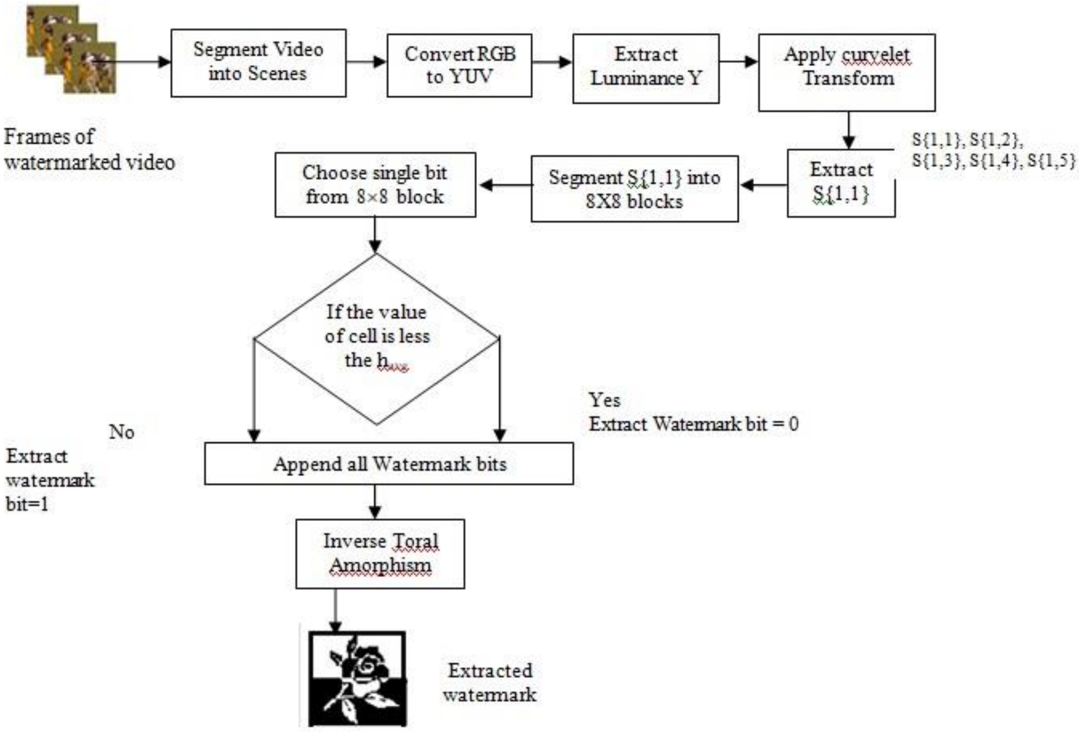

Fig.3. Video watermark extraction using Curvelet transform

A.Watermark Concealing Algorithm

The watermark concealing algorithm is shown in Fig. 2

1 .Segment covers video into scenes [5].

2. Convert frames of each scene from RGB to YUV, where U,V are chrominance components and Y is the luminance component [5]

3. Curvelet transform is applied to a squared image of size 2n ×2n and select this area in each frame for watermark insertion and for applying the Curvelet transform.

4. 4.If n=8, Curvelet transform decomposes the image into 5 scales S{1,1}, S{1,2}, S{1,3}, S{1,4}, S{1,5}. S{1,1} contains low pass filtered image and S{1,5} contains high pass filtered image and S{1,2}, S{1,3}, S{1,4} are mid frequency coefficients.

5. The size of S{1,1} is the same size of n2 as given in Table 1 of [13].

6. Segment watermark inserting area into 8×8 blocks.

7. Select first element in each 8×8 block for watermark insertion.

8. Quantize the low frequency coefficients from 0, 1, ⋯ 255 into m bins as shown in Table 1. After identifying the bin number m, S{1,1} is modified as follows

If watermark bit is 0 then it belongs to Range 1 where Range 1 is defined as Range 1 $h_{low}(m)$ to $h_{low}(m)+\frac{h_{low}(m)+h_{high}(m)}{2}$ then S{1,1}(i,j) is modified to S{1,1}(i, j) to $S\{1,1\}(i,j)^{new}$

$$S_{new}\{1,1\}(i,j)^{new}=\frac{\left(h_{low}(m)+\frac{h_{low}(m)+h_{high}(m)}{2}\right)}{2} \quad (5)$$

else if watermark bit is 1 then it belongs to Range 2 where Range 2 is defined as Range 2= h_{high} to $\frac{h_{high}+\frac{(h_{high}+h_{low})}{2}}{2}$ then S{1,1}(i,j,t) ismodified to S{1,1}(i,j)new as given below:

$$S_{new}\{1,1\}(i,j)^{new}=\frac{\left(h_{high}(m)+\frac{h_{low}(m)+h_{high}(m)}{2}\right)}{2} \quad (6)$$

9. If the watermark size is p×q, in each frame embed only (p×q/b) bits. Repeat this procedure of watermark insertion for b frames.

10.After this concatenate S{1,1}(i, j)new with S{1,2}, S{1,3}, S{1,4}, S{1,5}.

11. Apply inverse Curvelet transform.

12. Later convert color space from YUV to RGB. 13. Merge all the frames to obtain the marked video.

B. Watermark extraction Algorithm

Watermark extraction is performed on watermarked video to recover the extracted watermark. The methodology for watermark extraction is given in Fig 3 using the following steps.

1. Apply steps 1-6 in watermark concealing algorithm to watermarked video.

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2. Extract the bits where watermark is embedded from each 8 × 8 blocks. If $h_{ext}(m) \le \left(\frac{h_{low}(m)+h_{high}(m)}{2}\right)$ then watermark bit =0 else the watermark bit=1.
3. Append all the watermarked bits.
4. Apply inverse TA to obtain the extracted watermark.

Table 1: Selection of bins in Dither Quantization

Bit Number (m)	h_{low}	h_{high}
1	$d_{min}+\Delta$	d_{min}
2	$d_{min}+2\Delta$	$d_{min}+3\Delta$
3	$d_{min}+3\Delta$	$d_{min}+4\Delta$
. . .	. . .	. . .
b_{n-1}	$d_{max}-\Delta$	d_{max}
b_n	d_{max}	$d_{max}+\Delta$

IV. EXPERIMENTAL RESULTS

In this watermarking, the Common Intermediate Format (CIF) videos of spatial resolution 288 × 352 football, tempete, students and Paris are used. The test videos and corresponding watermarked frames are shown in Fig.4.

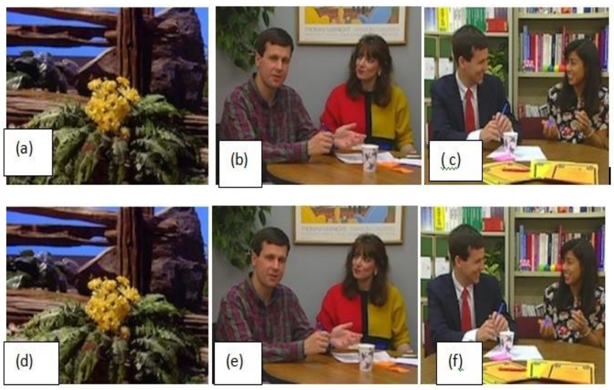

Fig.4. (a)Frames of Host video tempete, students and paris (b) Frames of watermarked video tempete, students and paris

The watermark is considered one eight of the spatial resolution of the video frame. In this, a binary image rose is taken as watermark. Since, Curvelet transform is applied to frames of size n^2, in each frame 256×256 portion is used for applying curvelet transform and the watermark insertion. The experiments are conducted on Matlab 2018 on Pentium 5 processor.The PSNR of Curvelet transform between watermarked and host video are 54.14 dB. The main advantage of the Curvelet transform is it has very less mean square error between the watermarked and host video. The objective fidelity criteria of the proposed watermarking scheme are obtained by the measures of mean square error and PSNR. Subjective evaluation is more suitable than objective evaluation for quality assessment. In the assessment, Double Stimulus Continuous Quality Scale (DSCQS) of ITU-R BT.500-11 standard.[14] is used. When performing a DSCQE test, the subjects must furnish the grading of quality of video between 5(very good) to 1(very bad). It has been agreed by 99% subjects that there is no visible distinction between host and signed video. The MOS of the proposed algorithm is compared with DWT-ABC [6] and CS-SCHT [5] and the high grading of MOS of the proposed algorithm shows that the algorithm is highly imperceptible. Watermarking scheme is made robust by placing the watermark in low frequency components of image. In image 92 % of energy is concentrated in low frequency portion of image.

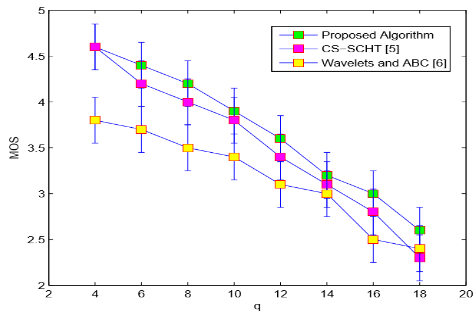

Fig 5. Mean opinion score of DWT-ABC, CS-SCHT and proposed watermarking scheme.

Fig.6. (a) Unsharp filtering, (b) Cropping to one-eighth portion of frame of video (c) Smoothing (d) Histogram Equalization (e) Rotation by 5◦ (f) Sharpening (g) Blurring due to camera movement (h)Circular Blur(g)H.264 Compression

(a) (b) (c) (d) (e) (f) (g) (h) (i)

Fig.7. Extracted rose obtained from (a) Unsharp filtering, (b) Central cropping (c) Smoothing (d) Contrast stretching (e) rotation (f) High pass filtering (g) Blurring due to camera movement (h)Circular Blur(g)H.264 Compression

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Table 2: Comparison of Average BER of wavelet and proposed for CIF video under divergent attacks: AF: without attack, US:Unsharpening, CR:Cropping, SM: Smoothing, CS:Contrast stretching, RO:Rotation, HPF: High Pass Filtering, BC: Blurring due to camera movement , H.264 : H.264 Compression

Transform	Attacks								
	NA	US	CR	SN	HE	RO	Sh	BC	H 264
Waveket (6)	0.0005	0.0916	0.185	0.025	0.06	0.107	0.036	0.04	0.227
Proposed	0.0002	0.0902	0.134	0.02	0.05	0.099	0.025	0.02	0.224

When performing a DSCQE test, the subjects must furnish the grading of quality of video between 5(very good) to 1(very bad). It has been agreed by 99% subjects that there is no visible distinction between host and signed video. The MOS of the proposed algorithm is compared with DWT-ABC [6] and CS-SCHT [5] and the high grading of MOS of the proposed algorithm shows that the algorithm is highly imperceptible. Watermarking scheme is made robust by placing the watermark in low frequency components of image. In image 92 % of energy is concentrated in low frequency portion of image. This portion of image is less sensitive to medication and robust to attacks. To make the watermarking scheme robust, the watermark bits should be placed in the most significant components of an image because this portion of the host data is robust to the attacks and highly sensitive to alteration. If the watermark is embedded in high frequency band, it is easily erased by using quantization or H.264 compression. So the watermark is embedded in low frequency Curvelet coefficients of host video.Signed frames of Football video with different attacks are shown in Fig. 6(a)-(h). .In unsharp filtering attack, a high pass filer is subtracted from frames of watermarked video as shown in Fig 6(a). In Cropping attack as shown in Fig. 6(b), central cropping is performed on watermarked video. Smoothing (AV) and Contrast stretching (CS) are applied as shown in Fig. 6(c) and (d). As this technique is based on curvelet transform, it shows robustness to rotation. Another two attacks based on blurring due to motion of camera and circular blur are shown in Fig. 6(e) and Fig. 6(f). H.264 compression is applied on watermarked video. The Bit Error Rate(BER) of proposed algorithm is less than Wavelet of [6] as shown in Table 2. This shows the proposed algorithm is more robust. central cropping and blurring due to camera movement. Hence, this algorithm fulfilling all the basic three requirements of watermarking-invisibility, robustness and security to make the watermarking scheme for secured video transmission in wireless communications

V. . CONCLUSION

The proposed watermarking exploits the curve singularities of Curvelet transform to provide security for the multimedia documents from the onslaught of piracy in wireless communication. The dither quantization is employed to hide the watermark in the transform coefficients of Curvelet transform. The algorithm is made more invisible with reduction in the mean square error between the original and marked video in Curvelet domain. Encrypted watermarking and selection of blocks for watermark concealing improved the security of watermark from unethical usage and protected the interests of copyright owners. The watermark is made robust to attacks by embedding watermark in approximation coefficients of video. The algorithm is found to be robust against attacks such as H.264 compression, High pass filtering, smoothing, contrast stretching, unsharp filtering,.

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