Real Time Implementation of Integer DCT based Video Watermarking Architecture

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Abstract: *With the recent development in multimedia communication network, data integrity and security of original content is the area of concern. Video is the one of the most popular object which is being shared easily throughout the media. Video watermarking is the current state of research to resolve the video ownership and authenticity related issues. There is a substantial amount of development in software based video watermarking from last few years. The prior works mainly focused on video watermarking that targeted for raw video where the watermark is embedded on the uncompressed video. At the present video capturing devices produce their output in one of the video compression standard. Software watermarking introduces a measurable quantity of delay between video capturing and watermark embedding process. Thus, software watermarking is not one of the ideal choices for real time watermark embedding. In the paper, a novel invisible and robust integer Discrete Cosine Transform (DCT) based video watermarking has been proposed. The proposed video watermarking is developed for real time watermark embedding and can easily be adapted as primary part of H.264 encoder. The proposed algorithm has an essential part in form of integer DCT. Integer DCT is implemented with two different approaches, one is with fully pipeline architecture and the other is recursive architecture, for better speed and area optimization. The robustness of the algorithm has been improved against some video attacks with introducing the concept of scene change detection.*

Keywords: *H.264, integer DCT, parallel processing, real time watermarking, recursive architecture.*

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1. Introduction

Digital video is an essential multimedia object which is transmitted through the channel [3]. The transmission of digital content has also imparted a challenge of secure communication from source to destination [17]. Digital video watermarking is the intelligent way of hiding owner's credential to prove the claim of ownership. H.264 is a block-oriented video compression standard which is jointly developed by ITU-T Video Coding Experts Group (VCEG) and ISO/IEC JTC Moving Picture Experts Group (MPEG) [1]. H.264 (MPEG-4 Part 10 advanced), is the latest standard and is developed for high quality video for low bit rate application devices like mobile phones, PDA etc., [19]. It has better quality as good as twice or four times compared to all previous video standards while having almost half of the bandwidth [10].

There are some commercial applications like video conference, movie production and video recording, video broadcasting system, where a real-time watermarking is the essential requirement [2, 7]. In such scenario, the software solution is not recommended because of the involvement of the delay between capturing the video and transmission over the channel [5]. There is a need to develop the custom hardware which resides in the electronics compliances such that watermark is embedded at the same time when it is being captured [12]. The real time embedding of the watermark can be done on raw video and along with the compression standard. With the demand of the applications, the bandwidth and data rates are challenging task for uncompressed or raw video. The compressed video watermarking satisfies the requirement of security at lesser bandwidth [6]. The present video capturing devices like mobile phones, digital camera, etc., are produced output in one of the compression standard [28]. Video compression systems operating at high speed and good quality requires efficient hardware architecture with high throughput for area and power optimization [21]. In the paper, real-time video watermarking algorithm for H.264 is explained. H.264 is standard which is based on integer arithmetic computation [22, 27]. Integer Discrete Cosine Transform (Int DCT) is the main module which is used for transformation from spatial domain to frequency domain [18]. Integer DCT has been implemented with two different approaches with fully parallel and recursive architecture. The recursive architecture approach uses same 1D DCT modules at different time interval to calculate 2D integer DCT. The fully parallel has two separate 1D integer DCT modules that run parallel to achieve overall 2D integer computation.

The paper is ordered as follows: Section 2 covers the literature survey of transform domain real time video watermarking. The detailed explanation of the proposed real time video watermarking algorithm is provided in section 3 In section 4, the architecture of for hardware implementation is illustrated and two different architectures for Int DCT are explained. Finally, the paper is illustrated with the results analysis of video watermarking algorithm in section 5 and the conclusion is implicated in section 6.

2. Related Transform Domain Real Time Video Watermarking

The arena of watermarking has started with image watermarking from past two decades [13]. The research of video watermarking has started a few years back. Earlier video watermarking algorithms were developed based on uncompressed domain and were not targeted for any standard. Then, real time requirement of watermark embedding has been noticed in applications like video broadcasting, Digital Versatile Disk (DVD) copy control, video authentication etc. [2, 14]. The electronics appliances are used to follow the video compression standard. The direction of research is going towards the development of video watermarking algorithm suited for the video standard [23]. Previously, many researchers have attempted transform domain real time watermarking which can be adapted with conventional video coding standard [9]. The real time performance of the algorithm has been defined with computational complexity of architecture. The video watermarking algorithm has evolved for variety of purposes such as copyright protection, proof of authenticity and ownership verification. The algorithm should comprise of fundamental requirements like robustness, imperceptibility, payload and blind detection. The robustness defines the stability of the algorithm against all form of attacks [24]. Imperceptibility signifies the visual distortion present in the content [25]. Payload is the vital parameter which defines the amount of data being embedded in original content with consideration of imperceptibility and robustness. Blind detection is useful to retrieve the watermark from the watermarked video without the access of original content.

Petitjean *et al.* [16] designed fractal coding based video watermarking for digital video compliance system. The work was useful for transform domain real time hardware implementation. The method was designed for MPEG-2 video compression standard. The algorithm was optimized and implemented on DSP, Very Long Instruction Word (VLIW) processor and subsequently prototyped on FPGA platform.

Vural *et al.* [26] introduced blind video watermarking for digital cinema using Discrete Wavelet Transform (DWT). The method was used to embed the watermark in low frequency coefficients of the frame in the video. The frame for watermark embedding was selected randomly using the hash function and the watermarking was performed to secure the content at the transmitter as well as at the receiver end. The payload of 256 bytes was embedded in the fifth level of wavelet sub band of 512×512 Lena image.

Mohanty *et al.* [15] presented perceptual based adaptive watermarking algorithm for video broadcasting system. This paper described VLSI architectures of DCT based real-time watermarking suited for MPEG-4 compression standard. The architecture was prototyped on Altera Cyclone II FPGA using VHDL.

Roy *et al.* [20] developed hardware architecture for semi fragile video watermarking on real time video authentication in surveillance camera. The proposed video algorithm was based on DCT method and could work as embedding chip for MJPEG video compression. The algorithm was tested with different frame size and simulated with Verilog hardware description language.

All previous transform domain video watermarking methods were based on MPEG video watermarking and insert perceptual and/or semi fragile watermark. MPEG and all prior video compression standards use the conventional floating path DCT implementation [8]. The corresponding MPEG based video watermarking schemes require heavy computational complexity because involvement of floating data structure therefore they are not useful in real time implementation. The proposed video watermarking scheme is mainly designed to have compatibility with integer arithmetic.

3. Proposed Real-Time Video Watermarking

Proposed video algorithm is based on H.264 video compression standard which uses integer DCT for transformation [11]. Each frame of a video is divided in the number of 8x8 blocks for 2D integer DCT [4]. In the paper, two different architectures of Integer DCT are developed for better speed and area. The algorithm uses a scene change detection technique for watermark embedding. This embedding method has the advantage against temporal attacks where loss of number of frames will not destroy the watermark.

Process of Embedding the Watermark:

Input: *Original video,* 8 *bit per pixel watermark.*
Output: *Secured watermarked video*.

- *Step* 1: *Original uncompresses (.yuv form) video is divided in the group frames using histogram difference method in order to detect the change of a scene.*
- *Step* 2: *Each frame from a group is processed by 8×8 block to compute the 2D Integer DCT.*
- *Step* 3: *The original watermark (i.e., a image in our experiments) is separated in the eight different planes. Each plane represents the part of original watermark and is treated as one watermark.*
- *Step* 4: *The different planes of a particular watermark are embedded in the subsequent frames of a particular group of video.*
- *Step* 5: *There will be large correlation among the frames of the video. The AC values can be estimated through DC values of*

the surrounding blocks as shown in Figure 1. AC values are predicted with help of Equations 1-5 as follows:

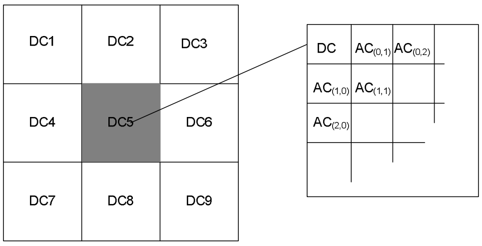


Figure 1. Prediction of AC values.

$$AC'_{(0,1)} = \left|9 * temp1\right| >> 6 \quad (1)$$

$$AC'_{(1,0)} = \left|9 * temp2\right| >> 6 \quad (2)$$

$$AC'_{(0,2)} = \left|temp3 - 2 * DC_5\right| >> 5 \quad (3)$$

$$AC'_{(2,0)} = \left|temp4 - 2 * DC_5\right| >> 5 \quad (4)$$

$$AC'_{(1,1)} = 3 * \left|temp5 - temp6\right| >> 7 \quad (5)$$

Where $temp1=(DC_4-DC_6)$, $temp2=(DC_2-DC_8)$, $temp3=(DC_4-DC_6)$, $temp4=(DC_2+DC_8)$, $temp5=(DC_1+DC_9)$, and $temp6=(DC_3+DC_7)$.

- *Step* 6: *To predict the AC values, simple arithmetic operations are used as shifting, addition/ subtraction and multiplication. Proposed watermark embedding algorithm has the integer arithmetic which is suitable for integer DCT.*
- *Step* 7: *The estimated values AC' are compared with original values obtained in Step 2. The small change in the form of* Δ *is added to original AC values according to the watermark.*

$$\begin{aligned}&\textit{If watermark bit} = 1\\ &\quad \textit{then } AC_i \geq AC'_i + \Delta\\ &\textit{else}\\ &\qquad AC_i \geq AC'_I - \Delta\end{aligned} \quad (6)$$

Process of Retrieving the Watermark:

Input: Secure Watermarked video.
Output: Retrieved watermark image.

- *Step* 1: *According to scene change detection method, the secure watermarked video is again separated in the different groups of frames.*
- *Step* 2: *Each frame from same group of the scene is transformed using 2D Int DCT. These values are used for the estimation of 5 AC coefficients with above Equations 1-5 in the embedding process.*
- *Step* 3: *For retrieval of the watermark, original AC values are compared with the estimated values as follows.*

$$\begin{aligned}&\textit{if } AC \geq AC'_i\\ &\quad \textit{Watermark bit}=1\\ &\textit{else}\\ &\quad \textit{Watermark bit}=0\end{aligned} \quad (7)$$

- *Step* 4: *With the retrieval of a bit, the watermark is constructed using different bit planes.*

4. Real Time Implementation of Proposed H.264 based Video Watermarking

Proposed H.264 based video watermarking is divided in two different and independent process as watermark processing and original frame processing. The architecture of the watermark algorithm is designed to have real time performance as represented in Figure 2. In the subsequent section, the detailed implementations of the modules are explained.

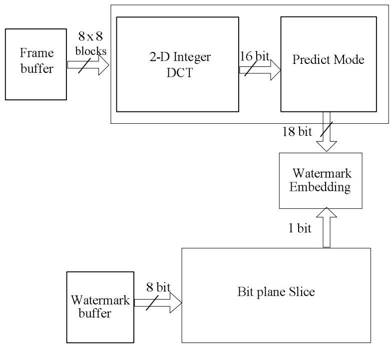


Figure 2. Prediction of AC values.

4.1. Implementation of Integer 2-D DCT

The original frames are stored in the frame buffer according to scene change detection. 2D DCT is executed with separable property. 1D DCT is calculated first with column processing and next time it is calculated with same manner for row processing. 2D DCT architecture has been implemented with two different approaches. In first recursive architecture, same 1D DCT is used for both column and row transformation. The transformed values of column DCT are stored and then applied to same 1D DCT for row transformation as shown in Figure 3.

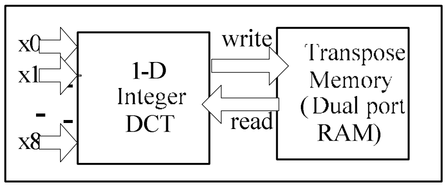


Figure 3. 2-D integer DCT with recursive architecture.

In second approach of full parallel architecture, two separate 1D DCT work in parallel as revealed in Figure 4. Dual port RAM is used as transpose memory to perform transposition operation where data are written in column manner and read in row wise. 1D Int DCT is computed with help of fast butterfly structure. At every clock cycle, 8×8 blocks of original frame have been read and processed from frame buffer.

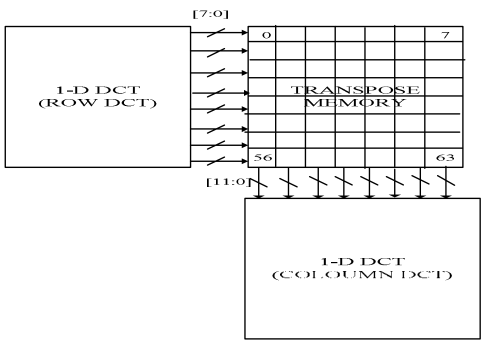


Figure 4. 2D integer DCT with fully parallel architecture.

4.2. Implementation of Prediction Module

The output of 2D DCT is applied to prediction module for the estimation of AC values which are further used during watermark embedding process. The values are predicted after one clock cycle delay through operations such as addition/subtraction, multiplication and shifting as shown in Figure 5. The predicted values AC' are used to compare with original AC values. According to a watermark bit, the small delta Δ (between 2 to 5) is added to generate watermarked frame.

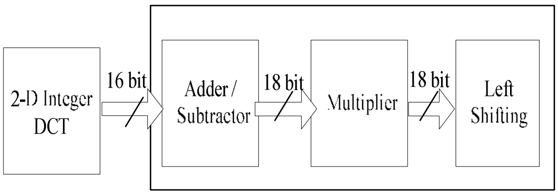


Figure 5. 2-D integer DCT fully parallel architecture.

4.3. Implementation of Bit Plane Slice Module

It is used to generate one bit watermark. It works in pipelining manner and is operated independently with respect to Integer 2D DCT and prediction process. The original watermark is processed from watermarked buffer. The values are used to perform bitwise AND operation with stored registered value of 1000_0000 as described in Figure 6. The output is compared with zero in order to generate one bit value. If the output is greater than zero then the watermark bit is one otherwise the watermark bit is zero. The generated watermark bit is embedded in a frame of the video.

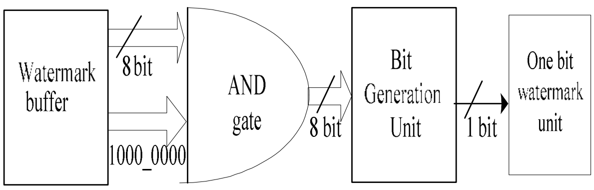


Figure 6. Bit plane slice architecture.

5. Results and Analysis

The performance is quantified with standard quality parameter such as Peak Signal to Noise Ratio (PSNR) and Mean Square Error (MSE) measurement.

$$MSE = \left(\frac{\sum_{m=1}^{M} \sum_{n=1}^{N} \left| p(m,n) - q(m,n) \right|^2}{M \times N} \right) \quad (7)$$

Where $p(m, n)$= pixel values of p frame, $q(m, n)$= pixel value of q frame. M=frame size of p, N=frame size of q.

$$PSNR = 10 \log_{10} \left(\frac{(2^k - 1)^2}{MSE} \right) \quad (8)$$

Where k= number of bit required to represent one pixel value.

For the simulation, "carphone.yuv" (frame size 144×176) is considered as original test video and 'peppers.png' (frame size 32×32) image is used as the original watermark, which are displayed in Figures 7-a and b respectively. The secure video after the embedding of watermark is shown in Figure 7-c.

a) Original video. b) Original watermark. c) Watermarked video.

Figure 7. Test video and watermark image.

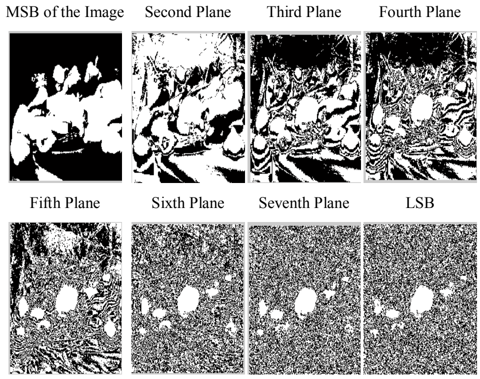


Figure 8. Different Planes of original watermark.

The eight different planes (MSB plane to LSB plane) of the original watermark are represented in Figure 8. MSE is the measurement of errors between two frames. PSNR is the logarithmic function and has inverse relation with MSE. In absence of an attack, average PSNR and MSE between original and watermarked frames of the video are around 54.274 and 0.243 respectively. The resulted values clarify the imperceptibility criterion of the watermark embedding process. The robustness of the proposed algorithm is quantified with Normalized Correlation (NC). NC is correlation between two frames and is calculated as follows.

$$NC(w, w') = \frac{\sum_{i=1}^{k-1} W \times W'}{\sqrt{\sum_{i=1}^{k-1} W^2} \sqrt{\sum_{i=1}^{k-1} W'^2}} \quad (9)$$

Where W=original watermark, W'=extracted watermark, and k=size of watermark.

The simulation results are obtained on MATLAB platform. The algorithm is tested against all the temporal attacks and results are reported in the form of NC as shown in Table 1. Some of the image based attacks are also considered for the particular frames and the performance of the algorithm is defined in Table 2. The minimum observed value of NC after retrieval of the watermark is around 0.87 which is quite good for any watermarking algorithm.

Table 1. Performance of algorithm against various temporal attacks.

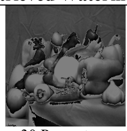
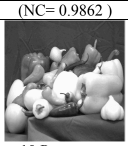
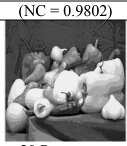
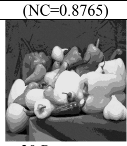
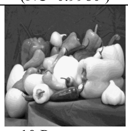
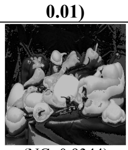
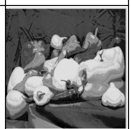
Attacks	Retrieved Watermark	Retrieved Watermark	Retrieved Watermark
Frame Dropping	 10 Percentage	 20 Percentage	 30 Percentage
	(NC= 0.9862)	(NC = 0.9802)	(NC=0.8765)
Frame Swapping	 10 Percentage	 20 Percentage	 30 Percentage
	(NC=0.9980)	(NC=0.9928)	(NC=0.9850)
Frame Averaging	 10 Percentage	 20 Percentage	 30 Percentage
	(NC=0.9979)	(NC=0.9432)	(NC=0.9321)

Table 2. Performance of algorithm against standard attacks.

Parameters	Gaussian Noise (0 Mean and Variance 0.01)	Salt and Pepper (Density 0.02)	Compression (10 Percent)
Normalized Correlation Between Original and Retrieved Watermark	 (NC=0.9344)	 (NC=0.9036)	 (NC=0.9802)
MSE	10.5239	15.1629	5.2291
PSNR	37.9090	36.3230	40.9465

In Table 2, MSE and PSNR are calculated between original frame and watermarked fame of the video. The lesser value of MSE indicates the imperceptibility of the proposed algorithm. From the experimental results obtained in Tables 1 and 2, the attained values signify the admirable performance of the proposed scheme. The algorithm poses the greater robustness against all the forms of attacks because of introduction of scene change detection method. The modules of the proposed methods have been synthesized with design compiler tools with 0.18 um Faraday library. The resultant area and power of all the required modules are noted in the Table 3 shown below.

Table 3. Synthesis results of the modules for the proposed watermark algorithm.

Modules	Area (μm^2)	Power (mw)
2-D Integer DCT Recursive Architecture	23998.00	196.90
2-D Integer DCT Fully Parallel Architecture	30115.00	255.19
Prediction Stage	951.00	6.65
Bit Plane Slice	192.00	0.023

Previous works of transform domain watermarking were based mainly on the MPEG based compression standard. Petitjean *et al.* [16] realized an watermarking method based on MPEG-2 standard which used general DCT method. Due to the involvement of floating point arithmetic, the architecture complexity increases and the performance of real time decreases. Vural *et al.* [26] designed watermarking scheme in frequency domain using wavelet transform but all the present standards imbibe DCT module for its transformation. Mohanty *et al.* [15] suggested the perceptual watermarking architecture for MPEG-4 application but it also requires the floating values in data path. This avoids the integration of the watermarking unit with H.264 standard which has mainly integer arithmetic.

Roy *et al.* [20] presented DCT based video watermarking for MJPEG standard. This algorithm embeds the semi fragile watermark which is used to detect any form of tempering for the frames of a video. The semi fragile watermarking has the feature that the watermark is capable to withstand some primary attacks while it demolishes in case of severe attacks beyond certain limit. The architecture requires heavy computational demands due to floating point operation. All the works defined in the past literatures were not robust against all attacks and is not useful as proof of ownership or not helpful any more as a court evidence. The proposed algorithm posses robustness against all the attacks and used to provide the authenticity. The proposed algorithm is compared with other real time transform domain video watermarking in Table 4. Two different architecture of 2D DCT are designed to have optimized results in area and speed respectively. Recursive approach of algorithm has better results for factors like area and power but suffers in terms of speed due to folded separable property of 2D DCT module. In the second fully pipeline design approach, the speed is achieved at the expense of area. The integer DCT unit has huge area because of the larger amount of memory requirement for the storage of original frame values and their transform values.

Table 4. Comparison watermarking architecture with previous work.

Research Work	Watermark Type	Domain	Standard	Frame Size	Results
Petitjean *et al.* [16]	Robust	Fractal	MPEG-2	512×512	6 μs for FPGA (50 MHz) 78 μs for Pentium III 118 μs for VLIW (250 MHz)
Vural *et al.* [26]	Invisible Robust	DWT	MPEG	512×512	NA
Mohanty *et al.* [15]	Visible	DCT	MPEG-4	320×240 x 3	100 MHz
Roy *et al.* [20]	Invisible Semi Fragile	DCT	MJPEG	640×480	0.18μ,10 mW, 40 MHz
Proposed (Recursive Approach)	Invisible Robust	Integer DCT	H.264	720×486	0.18μ,2.55 mm^2, 48.25 mW,37 MHz
Proposed (Fully Parallel Approach)	Invisible Robust	Integer DCT	H.264	720×486	0.18μ,3.20 mm^2, 62.5 mW,120 MHz

6. Conclusions

Parallel and pipeline architecture of the proposed video algorithm has been developed with Integer DCT implementation. The embedding process uses two different integer DCT architectures, one is Recursive DCT architecture and other is fully parallel architecture, with area and speed optimization for desired application. The proposed scheme has designed to adapt H.264 standard. The introduction of scene change detection concept has improved the performance significantly against temporal attacks.

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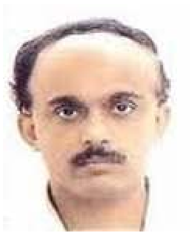

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