Digital Cinema Watermarking State of Art and Comparison

H. Kelkoul, Y. Zaz

***Abstract*—**Nowadays, the vigorous popularity of video processing techniques has resulted in an explosive growth of multimedia data illegal use. So, watermarking security has received much more attention. The purpose of this paper is to explore some watermarking techniques in order to observe their specificities and select the finest methods to apply in digital cinema domain against movie piracy by creating an invisible watermark that includes the date, time and the place where the hacking was done. We have studied three principal watermarking techniques in the frequency domain: Spread spectrum, Wavelet transform domain and finally the digital cinema watermarking transform domain. In this paper, a detailed technique is presented where embedding is performed using direct sequence spread spectrum technique in DWT transform domain. Experiment results shows that the algorithm provides high robustness and good imperceptibility.

***Keywords*—**Digital cinema, watermarking, wavelet, spread spectrum, JPEG2000.

I. Introduction

MANY pirated copies of movies can be accessible on the Internet or on the street markets before their official publication; with only a camcorder everybody can purchase a film from a movie theater.

Numerous papers have been broadcasted and studies still continue to find various security solutions for Digital cinema [27]-[29]. The economic influence of movies piracy, illegal VHS tapes, CD-Videos and DVD's is extremely enormous [10]. Lately, many digital watermark techniques have been offered for digital cinema as a security method [11]-[13].

The mean objective of our paper is to fight against movie piracy by creating an invisible watermark that includes the date, time and the place where the hacking was done. The watermark should be robust and resistant to several attacks like geometric distortions [1] and conversion A/D D/A [30]…

The following characteristics are fundamental for the design of a comprehensive video watermarking scheme [31]: The first characteristic is imperceptibility; the process of watermark embedding should not affect the quality of the host video. The second characteristic is robustness; the watermark must resist against common signal processing, which attempts to remove or impair the watermark signal [14]. The capacity characteristic is also important; the quantity of embedded information must be large enough to identify the owner of the host video.

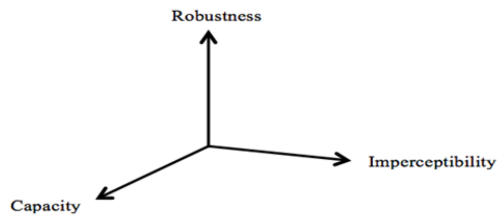

Fig. 1 Principal characteristics of an appropriate watermarking

This paper is organized as follows: Section I is the introduction, Sections II and III give a brief overview of the JPEG2000 and MPEG video compression standards. Section IV describes the watermarking techniques that have been tested in our research and finally in Section V we present an algorithm that combines the tested methods to adapt to the standards of the Digital Cinema Initiatives (DCI).

II. JPEG2000 Compression Standards

Created by the Joint Photographic Experts Group committee, the JPEG 2000 (JP2) is an image compression standard and coding system [16].

One of the latest applications to utilize JPEG2000 is digital cinema. The DCI specification defines the size of each movie frame to be as large as 4096x2160 pixels [2] with three-color components, 12-bits/pixel/color components, and 24 frames/ second.

JPEG2000 uses discrete wavelets transform and entropy coding. Two kinds of DWT are used; the 9/7 wavelet filter for lossy coding and the 5/3 wavelet filter for lossless coding [3].

III. MPEG Compression Standards

The MPEG standard is the first true multimedia standard with specifications for coding, compression, and transmission of audio, video [17]. According to Haskell and Puri, the primary requirement of the MPEG video standard was that it should achieve the high quality of the decoded motion video at a given bit-rate [32].

Each MPEG standard consists of different parts witch are further subdivided into profile and levels. The most popular standardized MPEG compression formats are the MPEG2 the MPG4 and the H.264.

Video coding uses spatial coding [8] by taking the DCT of 8×8 pixel blocks, quantizing the DCT, storing the DCT coefficients for each block in a zigzag scan, and doing a variable run length coding of the resulting DCT coefficient stream. Temporal coding is achieved by using the ideas of uni-

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and bi-directional motion compensated prediction, with three types of pictures resulting, namely:

- Intra or I pictures, which were coded independently of all previous or future pictures.
- P or Predictive pictures, which were coded based on previous P or I pictures.
- B or Bi-directionally predictive pictures, their coding are based on both the succeeding and/or the earlier pictures.

Fig. 2 MPEG Group of PICTURE GOP

IV. State of Art in Watermarking Techniques

Watermarking practices can be classified into spatial or frequency domain by place of application [18]. Spatial domain watermarking is implemented by modifying values of pixel color samples of a video frame, although watermarks of frequency domain systems are applied to coefficients obtained as the result of a frequency transform of either a whole frame or single block-shaped regions of a frame [19], [33]. Most usually used frequency transforms are:

1. Discrete Fourier Transform (DFT),
2. Discrete Cosine Transform (DCT)
3. Discrete Wavelet Transform (DWT).

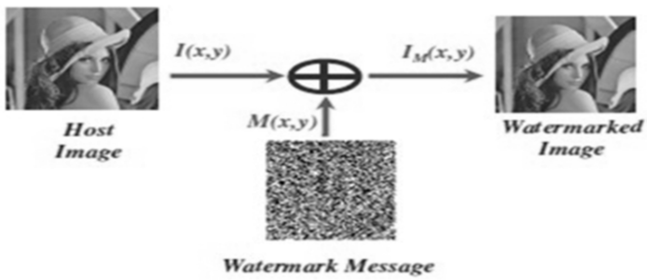

Fig. 3 Overview of Digital cinema watermarking

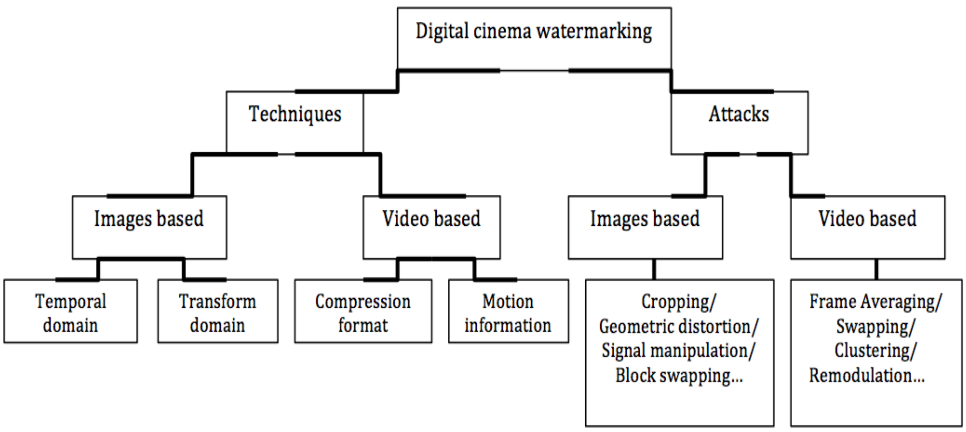

Fig. 4 Overview of Digital cinema watermarking

Practices used in image watermarking can be applied directly to the video watermarking, although video watermarking introduces some issues not present in image watermarking.

In the movies industry, the watermark could be embedded in uncompressed or compressed video [20]. Furthermore, the watermark should resist to geometrical distortions like zooming, cropping, rotation... Many researches describe watermarking schemes that are resistant to several geometrical distortions, like Fourier-Mellin transformation [21] or the autocorrelation [22] which is used to attain this robustness.

Additionally, Delannay et al. [23] investigated the restoration of geometrically distorted images occurred by the camera acquisition angles. The restitution of the alteration required both unmodified and modified video data.

There are only a few researches that study position of pirate estimation; Chupeau et al. [24] presented a forensic tracking system without embedding any mark on the video data. Likewise, Forensic watermarking provides a virtual system called "Chain of Custody" [25] for the digital cinema content that precisely establishes the source of illegal copies, track the address of the original source and made a copyright infringement over the digital video data [34].

The first technique we had experimented is the spread spectrum watermarking proposed by Cox et al. [4]. The principle of this technique is that a narrow band signal is transmitted over a much larger bandwidth such that the signal energy tested in any signal frequency (watermark) will be invisible. When the transformation DCT is applied to the compressed video, a perceptual mask is computed that highlights perceptual significant regions in the spectrum that can support the watermark without touching perceptual identity.

The process of watermark detection is done by concentrating the weak signals into a single signal with high signal-to-noise ratio [4]. According to Leung and Wong [35], experiment results show that this watermarking scheme is robust to traditional watermark attacks since the watermark is inserted in the perceptible significant regions of the video frames. Also, the watermark scheme has the weakness that it necessitates the original data in the extraction phase. consequently, only the owner can extract the watermark.

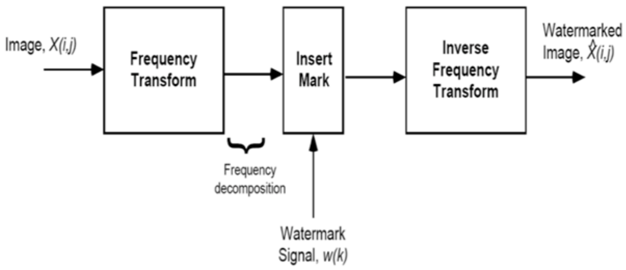

Fig. 5 Watermark insertion into most significant region of a spread spectrum-watermarking signal

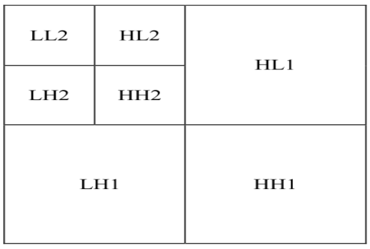

Fig. 6 DWT decomposition

The second technique that we have studied is the DWT watermarking provided by Prachi et al. [5]. According to [5], [19], the DWT divides the frequency band of a data frame into a lesser resolution estimation sub-band (LL) in addition to horizontal (HL), vertical (LH) and diagonal (HH) detail components. After that, watermark is embedded in low frequencies acquired by Wavelet decomposition.

To evaluate the performance of the DWT watermarking scheme against rotation and resizing attacks, Peak Signal to Noise Ratio (PSNR) is used to compute aberration of the watermarked and attacked frames [15] from the original video frames. The normalized coefficient (NC) is also used to gives a measure of the robustness of watermarking.

Attacks	**PSNR**	**NC**
Rotation	28,8	0,607
Resizing	39,46	0,6508

Fig. 7 Measure of robustness of watermarking against rotation and resizing attacks

- Higher values of PSNR indicate more imperceptibility of watermarking.
- The peak value of the NC is 1.

Subsequently we present a hybrid technique, which is a fusion of two methods. Here DWT and spread spectrum are used together, their fusion makes an efficient watermarking technique.

V. Proposed Algorithm about Digital Cinema Watermarking

In this section, we will present a watermarking scheme using spread spectrum technique in DWT domain.

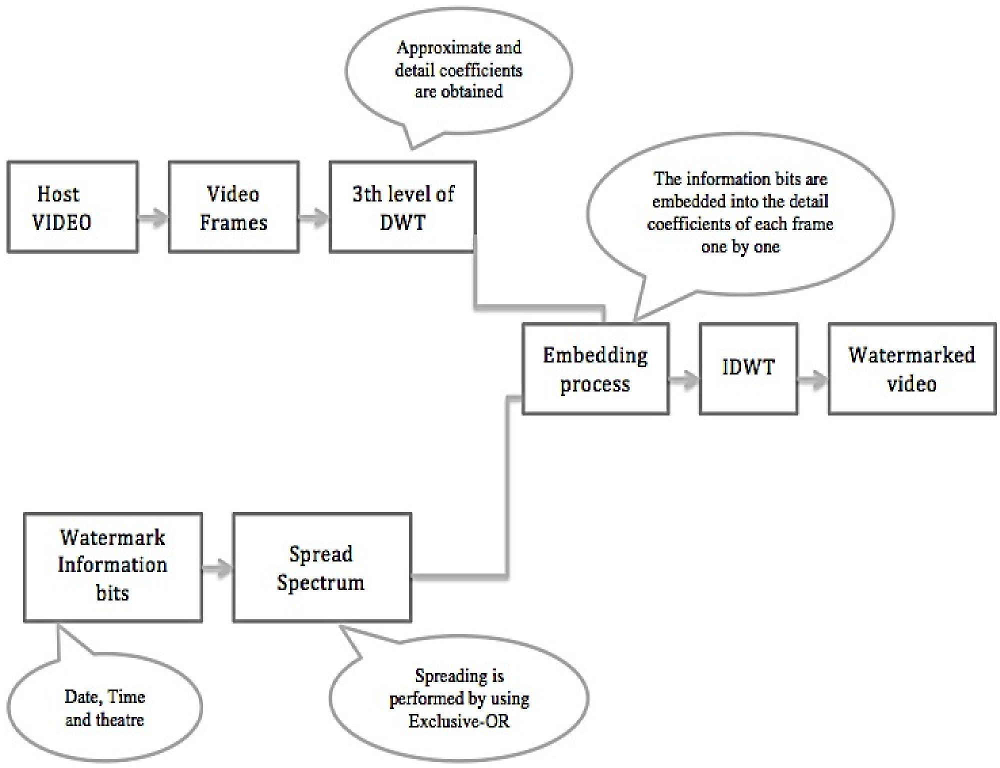

Fig. 8 Embedding process

The main aim of our work is to embed information into digital movies against camcorder piracy, such as the date the time and place of projection that allows to the forensic marking system to find the illegally captured movie in the Internet and tries to find out the pirate.

Fig. 8 shows the embedding process that we adopt in our algorithm. The watermark data are data text file (.txt) that includes the projection information like the time and the place of projection in the movie theatre.

The watermark is operated by using the direct sequence spread spectrum technique [26]. According to Xiang and Chansu [26], the direct sequence spread spectrum technique consists to divide the flow of bits to be transmitted into small pieces, each of which is apportioned across to a frequency band through the spectrum. The data text signal at the point of transmission is combined with a higher data-rate bit sequence that divides the text data conferring to a spreading ratio. According to [9], the redundant chipping code helps the signal oppose attacks and also allows the original data to be recuperated if data bits are impaired during transmission [9].

After spreading process, the watermark bits are

$$w'(i) = [1,-1,-1,1...N],\ 1 \le i \le N,$$

where N is the length of resulted watermark, which is t times more than original one.

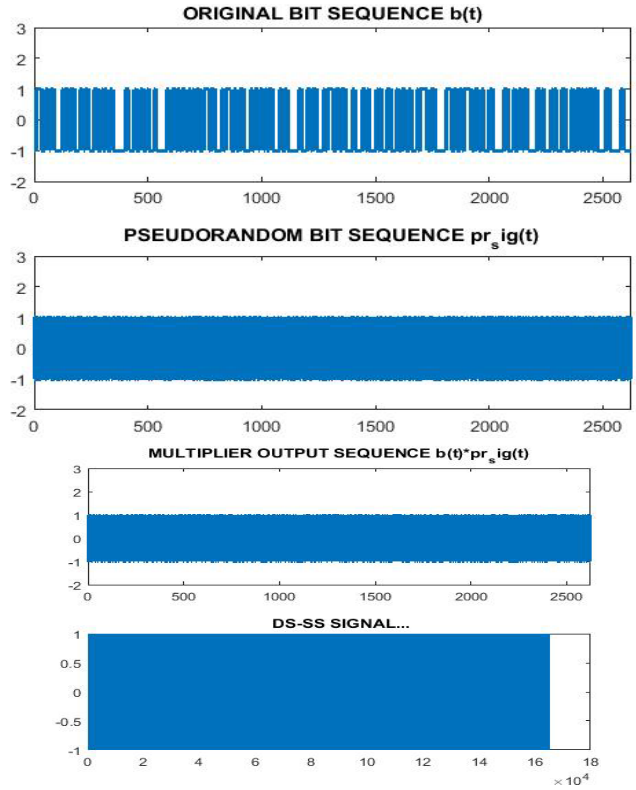

Fig. 9 Spreading data (txt) watermark

The video is converted into frames and each frame is decomposed into DWT third level and thus approximate and detail coefficients are obtained. For each message (text) bit, two different PN sequence vectors of size identical to the size of DWT column vector are generated. The watermark information is embedded in the detail coefficient using [6]:

$$Y(i) = \begin{cases} s'^{(i)} + \partial * w'^{(i)} & if\ w'^{(i)} = 1 \\ s'^{(i)} + \partial * w'^{(i)} & if\ w'^{(i)} = -1 \end{cases}$$

S'=Detail coefficient, α= watermark coefficient. Here as [36], we take benefit of the statistic specificity, such as mean and variance of the LHl, HLl, and HHl subbands, to modify the entire coefficients of them to vigorously implant the watermark and apply the cooperation between quality and robustness.

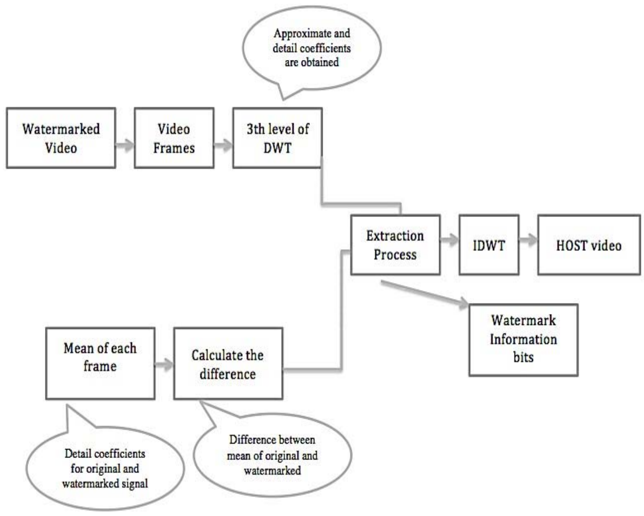

Fig. 10 Extraction process

The extraction process consists of splitting the watermarked video into frames and then decomposing each frame into DWT third level, afterward we calculate the main of detail coefficient between original and watermarked video.

The variance mean of original and watermarked signal is computed and watermark bits are extracted using [7]

$$w(s) = \begin{cases} 1\ if\ mean\ (new) - mean(original) \ge 0 \\ -1 f\ mean\ (new) - mean(original) \le 0 \end{cases}$$

After the watermark bits are extracted, the text data are recovered, and then we got all the information about the film projection.

VI. Experiment Results

Academics have been working and considered many different video-watermarking techniques. Each and every method has its unique advantages and disadvantages. To check the performances of the techniques, we have tested the application using MATLAB R 2015.a. Tests have been done on MPEG4 and JPEG 2000 video files. To check the effectiveness of the scheme, the algorithm is tested on standard video sequences with different resolutions, textures and motions. Imperceptibility is calculated by comparing their

PSNR values. Below the value PSNR= 27, the result is not suitable and then the aspect on imperceptivity is not respected.

$$PSNR = 10\log_{10}\left(\frac{MAX_1^2}{MSE}\right)$$

The Robustness is also calculated by computing the BER values (BER = Number of incorrectly decoded bits/Total number of bit). For random binary sequence watermark, as its value approaches zero the results remains correct.

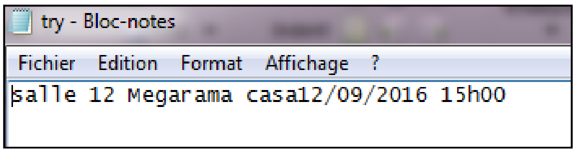

Fig. 11 Data (txt) watermark

The watermarking is in the form of a text (notepad) that includes the projection information: Cinema room date and time. The data text may also contain a serial number According to DCI requirement of the projected film or the name of the owner... It should be noted that as long as the text is long, this might impact the limit of the capacity of the proposed algorithm. Consequently, computational complexity and time consumption are the main issues related to this approach.

TABLE I
EXPERIMENT RESULTS FOR JPEG 2000 AND MPEG 4 COMPRESSION STANDARD

	BER		PSNR	
Experimented attacks	**JPEG 2000**	**MPEG4**	**JPEG 2000**	**MPEG4**
JPEG compression (QF 90)	**0.0054**	**0.062**	**40.47**	**29.5**
JPEG compression (QF 50)	**0.0189**	**0.082**	**41.15**	**30.09**
JPEG compression (QF 30)	**0.0167**	**0.142**	**41.3**	**32.11**
Salt and pepper noise (density =0.001)	**0**	**0.0614**	**33.9**	**27.9**
Salt and pepper noise (density =0.05)	**0.0314**	**0.114**	**29.3**	**26.01**

Experiment results in Table I prove that the watermarking technique provides better robustness for MJPEG2000 videos in comparison to MPEG4 videos.

Embedding the text data using the presented method performs better as compared to the application of DWT method or spread spectrum method separately.

VII. CONCLUSION

Agreed that many pirated copies of digital cinema are captured by the camcorder, our paper gives a scheme of video watermarking against video piracy based on spread spectrum in DWT domain. Experimental results prove that the presented technique offers better measures of robustness in comparison with the existing watermarking schemes.

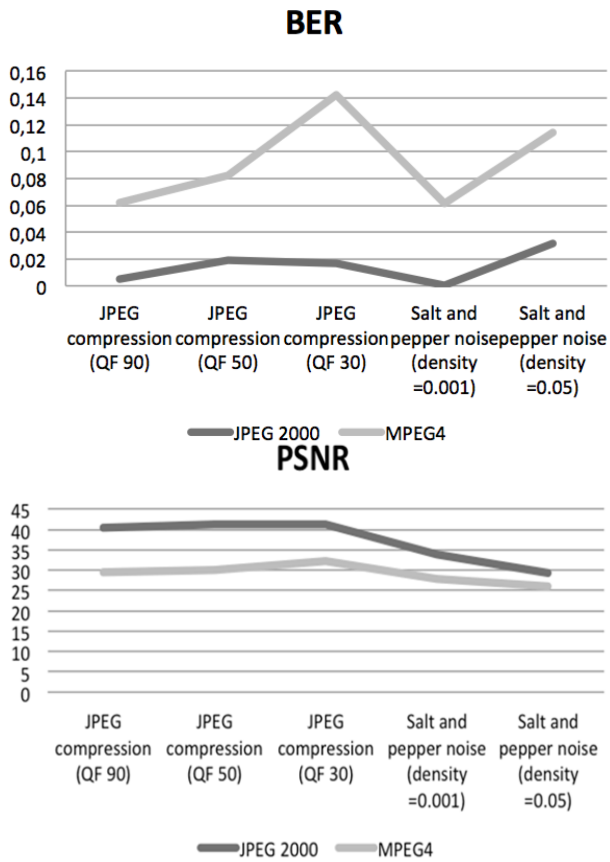

Fig. 12 Measures of robustness of watermarking scheme

Upcoming, we will adapt the algorithm to all the real time formats of videos either downloaded from the network or acquired across camcorders.

Our future works will be about how to precise the position of the pirate in the cinema room using the autocorrelation functions.

REFERENCES

[1] M. Alghoniemy and A. Tewfik, "Geometric distortion correction in image watermarking," in Proc. SPIE Security and Watermarking of Multimedia Contents II, vol. 3971, Jan. 2000, pp. 82–89.
[2] http://www.dcimovies.com/Digital Cinema Initiatives, LLC, Member. Representatives Committee, 9 July 2016.
[3] Boxin Shi, Lin Liu, Chao Xu State Key Laboratory of Machine Perception "Comparison between jpeg2000 and h.264 for digital cinema".
[4] Ingemar J. Cox, Joseph J. Kilian, Talal G. Shamoon "Secure spread spectrum watermarking for multimedia data" Volume: 6, Issue: 12, Dec 1997E.
[5] Nidhi Bisla, Prachi Chaudhary Electronics and communication engineering Department, DCRUST, Murthal, Haryana, India.
[6] N. Cvejic, "Algorithms for audio watermarking and steganography," Ph.D. dissertation, Department of Electrical and Information Engineering, Information Processing Laboratory, University of Oulu, 2004.
[7] M. Yiping and H. Jiqin, "Audio watermark in DCT domain: Strategy and algorithm," Chinese Journal Electronics, pp. 1260–1264, 2003.
[8] D. J. LeGall, "MPEG: A Video Compression Standard for Multimedia Applications,'' Communications of the ACM, Vol. 34, No.4, April 1991, pp. 47–58.
[9] http://searchnetworking.techtarget.com/definition/direct-sequence-spread, 20 January 2017

[10] Brian Larkin "Degraded Images, Distorted Sounds: Nigerian Video and the Infrastructure of Piracy" volume 16, Number 2, Spring 2004 pp. 289-314
[11] Akio, Miyazaki, "Digital Watermarking for images". IEICE Transactions. Fundamentals, Vol.E85-A, NO.3 March 2002, pp. 2
[12] N. J. Mathai, D. Kundur and A. Sheikholeslami, "HW Implementation Perspectives of Digital Video Watermarking," IEEE Transactions on Signal Processing, vol. 51, no. 4, pp. 925-938, April 2003
[13] Hisashi. Inoue, "A Digital Watermark method using the Wavelet Transform for Video Data", IEICE Trans. Fundamentals, Vol.E83-A,No.1 Jan2000
[14] Hou Zhi-yu et. al. "Integrity authentication scheme of color video based on the fragile watermarking". IEEE 2011.
[15] Tamanna Tabassum, S.M. Mohidul Islam, "A Digital Video Watermarking Technique based on identical frame extraction in 3-level DWT", IEEE, 2012.
[16] D.Santa Cruz T. Ebrahimi, "A study of JPEG2000 still image coding versus other standards" in Proceeding of the Xeuropean Signal Processing Conference (EUSIPCO), Tampere, Finland, September 58, vol.2, 2000, pp.673–676.
[17] D. J. LeGall, "MPEG: A Video Compression Standard for Multimedia Applications, Communications of the ACM, Vol. 34, No.4, April 1991, pp. 47–58.
[18] Hanane H. Mirza, Hien D. Thai, Yasunori Nagata and Zensho Nakao" Digital Video Watermarking Based on Principal Component Analysis" in Department of Electrical and Electronics Engineering, University of the Ryukyus Okinawa 9030213, Japan, 2011.
[19] Salwa A.K Mostafa, A. S. Tolba, F. M. Abdelkader, Hisham M. Elhindy, "Video Watermarking Scheme Based on Principal Component Analysis and Wavelet Transform"" IJCSNS International Journal of Computer Science and Network Security, vol.9 No.8, August 2009
[20] Xilinx Corp, "Digital Cinema Applications" www.xilinx.com August 2007.
[21] J. Ó Ruanaidh and T. Pun, "Rotation, scale and translation invariant digital image watermarking," in Proc. IEEE Int. Conf. on Image Process. 1997 (ICIP 97), 1, pp. 536–539, Santa Barbara, CA, USA, October 1997.
[22] M. Kutter, "Watermarking resisting to translation, rotation and scaling," in Proc. of SPIE, 3528, pp. 423–431, Boston, USA, November 1998.
[23] D. Delannay, J. Delaigle, B. Macq, and M. Barlaud, "Compensation of geometrical deformations for watermark extraction in the digital cinema application," in Proc. SPIE Security and Watermarking of Multimedia Contents III, Jan. 2003, vol. 4314, pp. 149–157.
[24] B. Chupeau, A. Massoudi, and F. Lefébvre, "In-theater piracy: Finding where the pirate was," in Proc. SPIE Security, Forensics, Steganography, and Watermarking of Multimedia Contents X, Jan. 2008, vol. 6819, pp. 68190T1–10
[25] G.C. Langelaar, I. Setyawan, R.I. Lagendijik, Watermarking digital image and video data, IEEE Signal Processing Magazine 17 (5) (2000) 20–46.
[26] Li. Xiang, Yu. Chansu, "Physical Layer Watermarking of Direct Sequence Spread Spectrum Signals," Beijing University of Posts and Telecommunications May, 2013.
[27] A. Leest, J. Haitsma, and T. Kalker, "On digital cinema and watermarking" in Proc. SPIE, 2001, vol. 5020, pp. 526–535.
[28] S. Vural, H. Tomii, and H. Yamauchi, "Robust digital cinema watermarking," International Journal of Information Technology, vol. 1, no. 1, pp. 255–259, April 2005.
[29] J. Lubin, J. Bloom, and H. Cheng, "Robust content dependent, high fidelity watermark for tracking in digital cinema" in Proc. SPIE, 2003, vol. 5020, pp. 536–545.
[30] Min-Jeong Leea, Kyung-Su Kima, Hae-Yeoun Leeb "Robust Watermark Detection Against D-A/A-D Conversion For Digital Cinema Using Local Auto-Correlation Function" Proceedings/ICIP4711782 International Conference on Image Processing, November 2008.
[31] Lubin, J., Bloom, J. A. and Cheng, H., "Robust, Content-Dependent, High-Fidelity Watermark for Tracking in Digital Cinema," Proc. SPIE, 5020, 536-545 (2003).
[32] B.G. Haskell, A. Puri, A.N. Netravali "Digital Video: An Introduction to MPEG-2" 2002, XIV, 441 p.
[33] Prachi V. Powar, S.S.Agrawal "Design of Digital Video Watermarking Scheme Using MATLAB Simulink" Volume: 02 Issue: 05 | May-2013.
[34] M. Adimoolam A. John Assistant Professor "Anti-Piracy for Movies using Forensic Watermarking" Vol 63 No.4, February 2013.
[35] Elo Leung and Wing Wong "A Study of Digital Watermarking System"CS265 Section 2 Spring 2004.
[36] Guoyan Liu, Hongjiun "Wavelet-Based Color Pathological Image Watermark through Dynamically Adjusting the Embedding Intensity" Volume 2012 (2012), Article ID 406349, 10 pages.