International Journal of Recent Technology and Engineering (IJRTE)
ISSN: 2277-3878 (Online), Volume-8, Issue-1, May 2019

Digital Watermarking of MPEG Videos using 2D Error Correcting Codes

Anjana Rodrigues, Archana Bhise

Abstract*: To protect the digital content from being copied, shared or deliberately stolen, Digital Rights Management has become important for digital content protection. Digital watermarking is a widely used method for copy protection, user authentication, author identification and many more tasks. A novel method of digital watermarking using 2-dimensional error correcting codes (2D-ECC) for copyright protection of MPEG videos is proposed in this paper. An invisible watermark is embedded in the motion vectors with a key. At the decoder, using the key, the watermark is extracted by the 2D-ECC and then the original motion vectors are retrieved. A wrong key or tampering of the motion vectors retrieves a highly distorted video. The PSNR values above 50 dB and SSIM values above 0.9 obtained for the watermarked video frames show that they are totally indistinguishable from the original ones. Also a high embedding capacity of 2 bits/pixel is obtained by preprocessing the watermark before embedding.

Index Terms*: 2D Error-correcting Codes, Copyright Protection, Digital Watermarking, MPEG Videos.

I. INTRODUCTION

Copyright protection has become a topic of immense importance in the era of digital communication. The security of a digital content can be compromised easily and multiple copies of an authorized content can be made by unauthorized persons. In such a scenario, it becomes difficult to ensure intellectual property rights to the rightful owner of digital content. Many methods have been proposed over the years by researchers and industry persons to overcome the problems of copyright infringement such as illegal claims of ownership, illegal distribution of copyrighted work, piracy, forgery and theft. The existing methods of copyright protection are watermarking, cryptography, steganography, Digital Rights Management (DRM) or combinations of any of these. Watermarking is the process of inserting some sort of an identification mark of the content owner inside the digital content in order to establish the rightful owner of the content in case a conflict arises. Watermarks can also be used to verify if the content is original or has been illegally duplicated, and to track the unauthorized user. Accordingly, there are three broad categories of watermarks: robust watermark, fragile watermark and semi-fragile watermark. Robust watermarks are used for copyright protection as it can resist various attacks, fragile watermarks are vulnerable to attacks and hence are used for for content authentication and tamper detection. Semi-fragile watermarks combine the advantages of both. They are used to distinguish signal processing operations from malicious attacks. Watermarks can be visible or invisible, but must not degrade the visual quality of the host content or interfere with its functionality in any way. The core intention of using watermarks is to establish the rightful owner of the content. It does not in any way attempt to prevent malevolent attacks to the content. Invisible watermarks should be imperceptible to the naked eye and robust to any intentional or unintentional processing that the content may undergo. In this paper, the authors propose a novel method of copyright protection of MPEG videos using robust digital watermarking in compressed domain, with 2-dimensional error correction codes (2D-ECC). 2D-ECCs are traditionally used to correct 2D random and burst errors arising due to intersymbol interference (ISI) in 2D data storage technologies such as 2D magnetic recording, optical holographic recording etc [1]. A distinctive feature of the 2D-ECC is its capability to correct single occurrences of multiple predetermined patterns of burst error within a codeword, with very few parity bits added. As the size of the codeword increases, so does its code rate and the number of patterns it can correct. A codeword of size (3, 5) has 10 message bits and 5 parity bits, and it can correct one burst error of size 1×1. Whereas a codeword of size (63, 63) requires 7 parity bits among a total of 63×63=3969 bits, and it can correct upto 8 different predetermined burst error patterns of size 2×2. This feature has been exploited in this paper wherein the watermark consisting of information such as details about the owner and authorized user and his rights regarding the use of digital content, is embedded in the motion vectors of the video to be protected, in the form of burst errors using 2D-ECC. The location of the burst patterns in the codeword can be decided by the content owner and can vary for every copy from user to user. At the receiver, the watermarked information is extracted from the motion vectors, the authenticity of the document is verified, the motion vectors are reset to their original value, and MPEG decoding is performed to play the video.

II. LITERATURE SURVEY

Literature survey lists some major works on digital watermarking which is the most popular method of copyright protection existing at present. Various techniques of watermarking have been proposed by different authors for the same.

Revised Manuscript Received on 30 May 2019.
* Correspondence Author
Anjana Rodrigues*, Department of Electronics and Telecommunication, Mukesh Patel School of Technology Management & Engineering, NMIMS, Mumbai, India.
Archana Bhise, Department of Electronics and Telecommunication, Mukesh Patel School of Technology Management & Engineering, NMIMS, Mumbai, India.

In the paper [2], the authors have proposed a method to embed a watermark in the wavelet coefficients of the LH, HL and HH sub-bands of the second wavelet decomposition level by quantization. A key has been used to spread the bits over a number of wavelet coefficients. This is a blind watermarking scheme, and does not require the availability of original image for watermark extraction. In a similar method in [3], use is made of the 3D coefficients of HL, LH and HH with their third level for embedding the watermark. A spread spectrum technique is used to embed the watermark into the selected wavelet coefficients. Both these methods provide robustness against attacks. Wavelet transform coefficients have been used for watermarking in similar ways for imperceptibility and to improve robustness [4-10].

Uncompressed video has been used by the authors in [11] to embed watermark in the DCT coefficients of the video frames, in conjunction with Quantization Index Modulation (QIM). QIM has also been used for multiple-symbol watermark embedding in [12]. A real-time dual watermarking algorithm of H. 264/AVC compressed video is proposed for Video-on-Demand (VOD) service [13]. The copyright information and user information are modulated by CDMA spreading strategies as watermark. An effective error compensation mechanism simultaneously introduced into the embedding process strictly restricts the distortion. In the method proposed in [14], the watermark is embedded into the luma components of the submacroblocks of the I frames and it does not sacrifice visual quality intensively. A content-based key is generated for random block selection, leading to enhanced security. A color watermark has been embedded by the authors in [15] using Contourlet Transform, Wavelet Transform and Singular Value Decomposition methods, and a two-level key is used for authentication. In [16], Complex Wavelet Transform has been used for watermarking. This method provides robustness against a variety of attacks such as compression, camcording, watermark estimation remodulation, temporal frame averaging, multiple watermark embedding, downscaling in resolution, and other geometric attacks, such as upscaling, rotation, and cropping. The authors have proposed a DRM method in which the embedding and extracting procedure are performed using the syntactic elements of the compressed bit stream in [17]. Based on the analysis of the time and space, some appropriate sub-blocks are selected for embedding watermarks, increasing watermark robustness while reducing the declination of the visual quality. In the proposed method in [18], data are embedded in the LL subband of wavelet coefficients in an adaptive manner based on the energy of high frequency subbands and visual saliency., and decoding is performed based on the comparison among the elements of the first principal component resulting from empirical principal component analysis (PCA). The proposed method offers improved performance under additive noise and compression attacks. A diverse watermarking technique has been proposed by authors in [19]. The authors have used different watermarking techniques in different frames to improve imperceptibility and protect from loss of fidelity with the original video. A comprehensive survey of various robust watermarking techniques has been presented in [23].

III. 2D ERROR-CORRECTING CODES

The basic theory of 2D cyclic codes was developed in [20] for correcting a single burst error of single error pattern. Later, it was shown in [1, 21], how the 2D cyclic code could be used as a 2D Error-Pattern-Correcting Code for correcting multiple predetermined error patterns by producing distinct syndrome sets for the error patterns. A set of zeros for a minimum parity code with error pattern detection capability is first generated. The set of zeros is then modified until it develops error pattern correction capability for single occurrence of a set of predetermined 2D error patterns.

A. Description of 2D Cyclic Codes

With reference to (Roy & Srinivasa, 2015), a 2D binary code **C** of size $M \times N$ is an array of M rows and N columns with elements from a finite field $GF(2)$, and can be represented in closed form expression as

$$c(x,y) = \sum_{(i,j)\in\Omega} c_{i,j} x^i y^j \tag{1}$$

where, $\Omega = \{(i,j)|0 \le i \le M-1, 0 \le j \le N-1\}$ and $c_{i,j} \in GF(2)$. Let $C[\Omega]$ denote the set of all possible bivariate polynomials. If $f(x,y) \in C[\Omega]$, then

$$\{f(x,y)\}_\Omega = f(x,y) mod (x^M - 1, y^N - 1) \tag{2}$$

Consider a bivariate polynomial $f(x,y)$. A point (x',y') is said to be a root of $f(x,y)$ if $f(x',y') = 0$. For a code of dimension $M \times N$, let γ and β be the primitive M^{th} and primitive N^{th} roots of unity respectively. The set of all such roots is given by $V = \{(\gamma^i, \beta^j)|0 \le i \le M-1, 0 \le j \le N-1\}$. From this set of zeros, a set of essential common zeros (ECZ) $\hat{V}_c$ is selected, which completely characterizes the 2D code.

B. Parity Check Tensor

The parity check tensor of the 2D code is an extension of the parity check matrix of the 1D code. Each element of the parity check tensor is a binary vector. Two zeros of $\hat{V}_c$ are said to be equivalent if their first components are conjugate over $GF(2)$. Thus, to find the parity position, $\hat{V}_c$ should be partitioned into equivalence classes. For any two roots (ε,η) and (θ,μ) to be equivalent for some positive integer k, $\varepsilon^{2^k} = \theta$. Each component of the parity check tensor, which is a binary vector, is split in length depending on the size of each equivalence classes. For a particular (i,j) coordinate of the tensor, $\gamma^i\beta^j$ is expressed in terms of $GF(2^{|V_{c_k}|})$ for the k^{th} segment. The set of all coordinates of the 2D code is defined as Ω. Let the set of the parity positions be defined by π, and the set of message positions be defined by $(\Omega - \pi)$. The binary vectors created at the parity position are all linearly independent. The binary vectors at the message positions can be expressed as a linear combination of these vectors. Each vector at the position (i,j) is expressed as

$$h_{i,j}(x,y) = \sum_{(k,l)\in\pi} h_{k,l}^{(i,j)} x^k y^l \tag{3}$$

where, $h_{k,l}^{(i,j)} \in GF(2)$ and $(i,j) \in \Omega$.

C. Generator Tensor

The relation between (i,j) components of the parity check tensor and the generator tensor is given by

$$g_{i,j}(x,y) = x^i y^j - h_{i,j}(x,y) \quad (4)$$

D. Generating the Codeword

The codeword for a given message polynomial is generated from the generator tensor. Let the message polynomial be

$$m(x,y) = \sum_{(i,j)\in\Omega} m_{i,j} x^i y^j \quad (5)$$

where $m_{i,j} = 0$ for $(i,j) \in \pi$ and $m_{i,j} \in GF(2)$ for $(i,j) \in (\Omega - \pi)$. The codeword, in polynomial form is then given by

$$c(x,y) = \sum_{(i,j)\in\Omega} m_{i,j} g_{i,j}(x,y) \quad (6)$$

In matrix form, $c(x,y)$ can be expressed as $C = [c_{i,j}]$, where the coefficients $c_{i,j}$ are given by

$$c_{i,j} = \begin{cases} -s_{i,j}, & (i,j) \in \pi \\ m_{i,j}, & otherwise \end{cases}$$

A codeword is said to be a valid codeword if it satisfies the condition

$$\sum_{(i,j)\in\Omega} c_{i,j} h_{i,j}(x,y) = 0 \quad (7)$$

IV. PROPOSED METHOD

The proposed method uses 2D error-correcting codes to embed author and user details into the motion vectors of the video to be protected. The motion vectors are arranged in a two-dimensional matrix of size 3×5. A modification made by the authors in the basic 2D-ECC is that motion vectors have been used in decimal form itself, as positive and negative integers, instead of converting to binary. Also, the motion vectors are used at parity bit positions also instead of zero. The values of motion vectors at parity bit positions are processed and a key is derived from this information, using which these motion vector values at parity bits positions can be correctly retrieved at the decoder.

A. Watermark Pre-processing

The watermark is subjected to a pre-processing stage wherein, it is first converted to binary. Then, it is grouped into blocks of four bits each, and each block converted to decimal form. It is then inserted into the motion vectors as if it is a burst error, by changing the motion vector at the location indicated by the decimal number by one. Thus, four binary bits can be embedded by changing just one motion vector value by one, which is equivalent to embedding 2 bits/pixel. The embedding capacity is hence improved to a great extent as compared to many existing methods. The inverse is done at the decoder to retrieve the watermark. Fig. 1 depicts the method of implementation on a block of motion vectors.

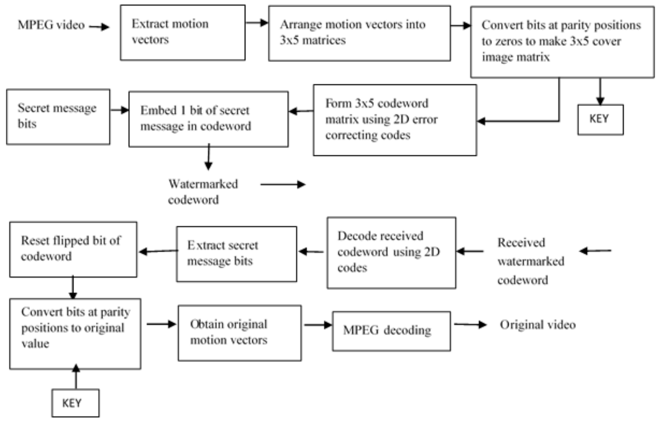

Figure 1. Block diagram of embedding and retrieving process

B. Embedding Process

A binary two-dimensional code of size 3×5 over $GF(2)$ is used for demonstrating the embedding and retrieving process. The codeword is generated by the ideal basis of the following two arbitrary polynomials:

$$g_1(x,y) = (x+1)(y^2 + x^2 y + 1) \quad (8)$$

$$g_2(x,y) = (x^2 + x + 1)(y + 1) \quad (9)$$

Let the primitive polynomial considered be $(x^4 + x + 1)$ having a root α. Let γ be the primitive cubic root of unity and β be the primitive fifth root of unity. Then,

$$\gamma = \alpha^5 \text{ and } \beta = \alpha^3$$

The set of essential common zeros (ECZ) of $g_1(x,y)$ and $g_2(x,y)$ is given by

$$\hat{V}_c = \{(\gamma,\beta),(1,1)\}$$

Using the set of ECZs, the parity check tensor is obtained as

$$H = \begin{bmatrix} (10001) & (00011) & (00111) & (01011) & (11111) \\ (01101) & (10101) & (01111) & (10011) & (00101) \\ (11101) & (10111) & (01001) & (11001) & (11011) \end{bmatrix}$$

From the set of ECZs, the number of check symbols and their positions can be determined. The check symbols are obtained at positions $(0,0), (0,1), (1,0), (1,1)$ and $(2,0)$, represented by the locations in π of the codeword and the remaining symbols at locations in $\Omega - \pi$ represent the message.

The elements of the check tensor can be represented as $H = [h_{k,l}]$. The elements $(h_{k,l}|(k,l) \in |pi)$ are linearly independent over $GF(2)$, and any element of **H** can be expanded in terms of $h_{k,l}$ with coefficients from $GF(2)$ to obtain the polynomial $h_{i,j}(x,y)$. The generator polynomial is generated using (4). The message polynomial comprises of motion vectors. Fifteen motion vectors are taken at a time.

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

The values of the motion vectors at the five parity check positions is noted down. These position informations are used to derive a key, which is then used for correct retrieval of the motion vectors at the receiver. The fifteen motion vectors are arranged in the form of a 3×5 matrix, where $m_1, m_2, \ldots, m_{10}$ represent the message symbols and $p_1, p_2, \ldots, p_5$ represent the parity bits.

$$m(i,j) = \begin{bmatrix} p_1 & p_4 & m_2 & m_5 & m_8 \\ p_2 & p_5 & m_3 & m_6 & m_9 \\ p_3 & m_1 & m_4 & m_7 & m_{10} \end{bmatrix}$$

An example of a message matrix is shown below.

$$m(i,j) = \begin{bmatrix} 1 & 5 & -3 & 8 & 0 \\ 0 & 6 & 1 & -6 & 3 \\ 3 & 2 & 4 & -2 & 7 \end{bmatrix}$$

The codeword is generated using equation (6). In matrix form, the codeword can be written as

$$c(i,j) = \begin{bmatrix} -2 & -9 & -3 & 8 & 0 \\ -10 & -19 & 1 & -6 & 3 \\ -6 & 2 & 4 & -2 & 7 \end{bmatrix}$$

This process is repeated until all the motion vectors are encoded.

After the codewords are obtained, sequentially one pre-processed watermark number (represented in the decimal form) is embedded into each codeword, as if a burst error has occurred. The procedure has been explained earlier in this section. Here, the authors are considering the burst pattern of the error to be 1×1. The 2D error-correcting code of size 3×5 is capable of correcting a 1×1 burst error anywhere in the region Ω. After the watermark is introduced in the codeword, the codeword (which actually comprises of the motion vectors) is corrupted and becomes the watermarked codeword as shown below.

$$c\_wm(i,j) = \begin{bmatrix} -2 & -9 & -2 & 8 & 0 \\ -10 & -19 & 1 & -6 & 3 \\ -6 & 2 & 4 & -2 & 7 \end{bmatrix}$$

The watermarked codeword is transmitted to the receiver where the watermark is extracted using 2D-ECC and the codeword is corrected before applying MPEG decoding to run the video.

C. Retrieving Process

Received codeword contains watermark message embedded in blocks of size 3×5. To retrieve this, each block is multiplied by the parity check tensor to obtain the residue, as given by

$$R_{i,j}(x,y) = \sum_{(i,j)\in\Omega} r_{i,j} h_{i,j}(x,y) \qquad (10)$$

where $r_{i,j}$ are the elements of the received codeword. Using equation (10), the residue of the received codeword for the example given in the embedding process is

$$R_{i,j}(x,y) = x + x^2 + y$$

The residue obtained corresponds to the parity check tensor of that element of the message that was embedded with the

(a)

(b)

Figure 2. (a) original video frames of Dolby (b) watermarked video frames of Dolby

(a)

(b)

Figure 3. (a) original video frames of Rhino (b) watermarked video frames of Rhino

(a)

(b)

Figure 4. (a) original video frames of Lion (b) watermarked video frames of Lion

watermark, namely $h_{1,3}(x,y)$. Thus the watermark can be retrieved and the corresponding motion vector restored to its original value.

The motion vectors in the parity positions too are restored to their original values using key, in order to enable correct reconstruction of the video frames. Correct retrieval of the watermark ensures proper reconstruction of the video frames.

V. RESULTS AND DISCUSSION

The proposed method is implemented on the motion vectors of all frames located just before each I frame in videos coded using MPEG coding. This is done to avoid the error in these frames from affecting other frames in the same Group of Pictures (GOP). The results on few selected frames of three sample videos, Dolby, Rhino and Lion, are shown here. The three videos have been selected in such a way that the temporal frequency of the objects in Dolby is high, of Rhino is medium, whereas Lion has least temporal frequency. Hence any changes in the motion vectors of Lion due to watermarking is likely to produce more distortion than in Dolby, which can also been seen from the results' table. As this method uses motion vectors for hiding the secret information, videos coded using MPEG-2 or MPEG-4 can be considered as cover image. The first, sixth, eleventh etc. frames are coded as I-frames. The watermark is inserted into the motion vectors of the fifth, tenth, fifteenth etc. frames by using the proposed method of watermarking to obtain watermarked motion vectors and hence the watermarked video. At the receiver, the watermark is extracted first and the motion vectors are restored to their original value by the proposed watermarking method. MPEG decoding principles are then applied and the host video is played. Original frames and corresponding watermarked frames of the videos are shown in the Figs. 2, 3 and 4 respectively.

It is observed that the frames shown in Figs. 2(b), 3(b) and 4(b) have no perceptual distortion and have high visual quality. The results of PSNR and Structural Similarity (SSIM) index [22], obtained after implementing this algorithm on various cover videos are tabulated in Table 1. PSNR and SSIM index value of each affected frame is calculated and average value is taken. The results in Table 1 are in agreement with the subjective quality of watermarked videos observed in the figures. The values of PSNR in the range of 50-55 dB are far above the acceptable standard of 30 dB minimum. A comparison with the method in [18] is also given, which shows better values of PSNR for the proposed method. SSIM index of the watermarked videos are all above the acceptable value of 0.9 for undistorted viewing, which indicates that the watermarked video frames are highly comparable to the original frames, so that a person trying to make a duplicate version will not be able to detect the presence of the watermark in it. This proves that it is possible to view the videos without distortion in spite of the presence of embedded data. The versatility of the code, in that it allows embedding multiple bits of different patterns in variable locations in each block enhances the security of the method.

Motion vectors are the key information for expressing the video content during the encoding process and the decoding process, hence they constitute an important part of the coded bit stream. So they are losslessly coded. Secondly, the visual quality degradation introduced by embedding data in motion vectors is relatively limited through the motion compensation and the residue coding, thus giving high imperceptibility to the watermark. Since a robust watermarking method has been used to hide the details, it is extremely difficult to extract these information, reset the motion vectors to their original value, and play the correct video. Thus the proposed method discourages tampering of the watermark and making pirated copies of the videos as only the watermarked versions can be pirated and tracing the offender becomes easy.

Table I. Performance parameters measured on watermarked videos after implementing proposed method

Cover Video	Proposed method		Empirical PCA based decoding
	PSNR (dB)	SSIM	PSNR (dB)
Dolby	55	0.96	51
Rhino	52	0.94	51
Lion	50.4	0.91	51

VI. CONCLUSION

In this paper, copyright protection with digital watermarking using 2D-ECC has been proposed, which is a novel concept. It has been developed for MPEG videos. The motion vectors of the videos are modified with the watermark using the principles of 2D error-correcting codes as the basis for replacement. The authenticity of the document is verified by the receiver which initiates the 2D ECC decoder and enables retrieval of the original motion vectors and the embedded message. The average PSNR of the watermarked videos is greater than 50 dB and the SSIM is more than 0.9 in all the cases. An embedding capacity of 2 bits/pixel is also obtained. Thus, the proposed watermarking process maintains a very good imperceptibility of the watermarked video, at the same time giving a high embedding capacity.

REFERENCES

1. S. W. Yoon, and J. Moon, "Two-dimensional error -pattern- correcting codes," IEEE Transactions on Communications, vol. 63, no. 8, August 2015, pp. 2725-2740.
2. R. O. Preda, and D. N. Vizireanu, "A robust digital watermarking scheme for video copyright protection in the wavelet domain," Measurement, vol. 43, no. 10, 2010, pp. 1720-1726.
3. M. Masoumi, and S. Amiri, "A blind scene-based watermarking for video copyright protection," AEU-International Journal of Electronics and Communications, vol. 67, no. 6, 2013, pp. 528-535.
4. P. Ghosh, R. Ghosh, S. Sinha, U. Mukhopadhyay, D. K. Kole, and A. Chakroborty, "A novel digital watermarking technique for video copyright protection," CS & IT, vol. 6, 2012, pp. 601-609.
5. S. Sinha, P. Bardhan, S. Pramanick, A. Jagatramka, D. K. Kole, and A. Chakraborty, "Digital video watermarking using discrete wavelet transform and principal component analysis," International Journal of Wisdom Based Computing, vol. 1, no. 2, 2011, pp. 7-12.
6. H. Khalilian, and I. V. Bajić, "Multiplicative video watermarking with semi-blind maximum likelihood decoding for copyright protection," In Communications, Computers and Signal Processing (PacRim), August 2011, IEEE Pacific Rim Conference on, 2011, pp. 125-130.
7. O. S. Faragallah, "Efficient video watermarking based on singular value decomposition in the discrete wavelet transform domain," AEU-International Journal of Electronics and Communications, vol. 67, no. 3, 2013, pp. 189-196.
8. N. I. Yassin, N. M. Salem, and M. I. El Adawy, "Block based video watermarking scheme using wavelet transform and principle component analysis," International Journal of Computer Science Issues (IJCSI), vol. 9, no. 1, 2012, p. 296.

9. J. Wassermann, "New robust video watermarking techniques based on DWT transform and spread spectrum of basis images of 2D Hadamard transform," In International Conference on Multimedia Communications, Services and Security, Springer, Berlin, Heidelberg, June 2013, pp. 298-308.
10. T. R. Singh, K. M. Singh, and S. Roy, S, "Video watermarking scheme based on visual cryptography and scene change detection," AEU-International Journal of Electronics and Communications, vol. 67, no. 8, 2013, pp. 645-651.
11. H. Y. Huang, C. H. Yang, and W. H. Hsu, "A video watermarking technique based on pseudo-3-D DCT and quantization index modulation," IEEE transactions on information forensics and security," vol. 5, no.4, 2010, pp. 625-637.
12. M. Hasnaoui, and M. Mitrea, "Multi-symbol QIM video watermarking," Signal Processing: Image Communication, vol. 29, no. 1, 2014, pp. 107-127.
13. Y. He, G. Yang, and N. Zhu, "A real-time dual watermarking algorithm of H. 264/AVC video stream for Video-on-Demand service," AEU-International Journal of Electronics and Communications, vol. 66, no.4, 2012, pp. 305-312.
14. A. Mansouri, A. M. Aznaveh, F. Torkamani-Azar, and F. Kurugollu, "A low complexity video watermarking in H. 264 compressed domain," IEEE Transactions on Information Forensics and Security, vol. 5, no.4, 2010, pp. 649-657.
15. L. Agilandeeswari, and K. Ganesan, "A robust color video watermarking scheme based on hybrid embedding techniques," Multimedia Tools and Applications, vol. 75, no. 14, 2016, pp. 8745-8780.
16. M. Asikuzzaman, M. J. Alam, A. J. Lambert, and M. R. Pickering, "Imperceptible and robust blind video watermarking using chrominance embedding: a set of approaches in the DT CWT domain," IEEE Transactions on Information Forensics and Security, vol. 9, no. 9, 2014, pp. 1502-1517.
17. Z. Ma, J. Huang, M. Jiang, and X. Niu, "A video watermarking DRM method based on H. 264 compressed domain with low bit-rate increasement," Chinese Journal of Electronics, vol. 25, no. 4, 2016, pp. 641-647.
18. H. Khalilian, and I. V. Bajic, "Video watermarking with empirical PCA-based decoding," IEEE transactions on image processing, vol. 22, no. 12, 2013, pp. 4825-4840.
19. Y. Gupta, S. Agrawal, S. Sengupta, and A. Chakraborty, "Digital video watermarking using diverse watermarking schemes," In Advanced Methodologies and Technologies in System Security, Information Privacy, and Forensics, IGI Global, 2019, pp. 191-205..
20. H. Imai, "A theory of two-dimensional cyclic codes," Information and Control, vol. 34, no. 1, 1977, pp. 1-21.
21. S. Roy, and S. G. Srinivasa, "Two dimensional error-correcting codes using finite field Fourier transform," In Information Theory Workshop-Fall (ITW), IEEE, October 2015, pp. 119-123.
22. Z. Wang, A. C. Bovik, H. R. Sheikh, and E. P. Simoncelli, "Image quality assessment: from error visibility to structural similarity," IEEE Transactions on Image Processing, vol. 13, no. 4, 2004, pp. 600-612.
23. X. Yu, C. Wang, and X. Zhou, "A Survey on Robust Video Watermarking Algorithms for Copyright Protection," In Applied Sciences, vol. 8, no. 10, 2018, p. 1891.

AUTHORS PROFILE

Anjana Rodrigues graduated in Electrical Engineering from REC Calicut, India in 1997. She did her post-graduation in 2012 from Fr.CRCE, India and is currently pursuing Ph.D from MPSTME, India. She has 4 years of industrial experience and 15 years of teaching experience in engineering discipline. Presently, she is working with NMIMS, Mukesh Patel School of Technology Management and Engineering, Mumbai, India. Her main interests are image and video steganography and watermarking, power electronics, and electrical networks. She is a member (ISTE).

Archana Bhise graduated from SGSITS, India in 1984. She did her post-graduation in 1995 from VJTI, India and Ph.D in Electronics and Telecommunication in 2013 from RGPV, India. She has 30 years of teaching experience in engineering discipline. Presently, she is working with NMIMS, Mukesh Patel School of Technology Management and Engineering, Mumbai, India. Her main interests are error correcting codes, cryptography and signal processing. Dr. Bhise is a member (ISTE), fellow member (IETE) and member (IET).