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Compressive Sampling in SWT-SVD-Based Video Watermarking with RS Code

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Abstract

Watermarking is a way to protect the copyrights of multimedia products by inserting the information (watermark) into the multimedia data (media host). The size of the watermark must be small from the host media so that the watermark does not damage the quality of the host media. Image compression uses compressive sampling-based on RS Code and Discrete Sine Transform (DST). Watermark insertion is processed on the frame of the video that has been compressed in the embedding process using Stationary Wavelet Transform (SWT) and Singular Value Decomposition (SVD) are used as data insertion methods, and OMP is proposed for image reconstruction. Compressive sampling can be used as a compression method with an average BER value of 0.152 and PSNR 33.848. This system is resistant to Gaussian Blur, Salt and Paper, and Rescaling attacks.

Keywords: *Video Watermarking; Stationary Wavelet Transform; Discrete Sine Transform; Singular Value Decomposition; RS Code; Compressive Sampling*

I. INTRODUCTION

Nowadays, video technology is an important part of multimedia communication. The video present information that can combine text, image, and audio information. Video technology has been applied in various field of life like medical, entertainment, entrepreneurship, information, education, etc. Besides the advantages of video technology, it has the disadvantages too, one of them is it can provide an opportunity for people to disseminate information on digital media illegally. Watermarking is the process of tagging, labelling or marking which can be done on digital media with the purpose to give the copyright or signature that extracted to digital media confidentially but it did not see different with the original. One of watermarking requirement is imperceptible. It means that watermark cannot be visually or auditory perception because watermark must not damage the quality of host media, and the size of watermark must be smaller than the host media. From those requirements, we can conclude that the watermarking process needs a compression process of the watermark.

Many studies have been conducted using different methods. Following are some methods related to the watermarking process in this research. The selection of the DST method refers to research [1] it can be explained that DST is a transformation with the compaction properties are higher than DFT. In the other side, DST two times faster than DCT. It is asymmetrical transformation which only needs a real operation, thus making it quick to do a transformation. The use of Compressive Sampling refers to research [2] which explaining that Compressive Sampling can recover certain signal and image from samples or fewer measurements. It is evidenced by the fourth iteration with the value of BER is 0.022. On research [3] has explained that Compressive Sensing can perform the compression process on image watermarking with the good performance that produces the value of BER closer to 0, the value of SSIM closer to 1 and the value of PSNR exceeds 50. And then this study are using SWT and SVD methods that refers to research [4] which has been concluded that SWT and SVD methods can improve the robustness of audio watermarking and it has provided the result that the attack of SMBA 82.61% can be well anticipated with the value of BER is smaller than 10%

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and the average value of SNR is 32.72 dB. On research [5] has produced that the average value of PSNR is 97.55 dB which is better. Thus the quality of watermark image is better and have more ability to restrain the attack that may cause loss of the hidden information on digital media. This technique can be applied for video watermarking and to embed the watermark. In this study also apply an error correction of RS code that refers to research [6] which shows that RS Code fulfilled the basic requirements of watermarking and the value of compression process is higher and reached 91.3% that made the watermarks become robust. The reconstruction method refers to research [7] which mentioned that the OMP reconstruction has advantages to reconstruct the watermarked image practically, faster, and increase the accuracy with the average value of PSNR is 29.175 dB, and it is suitable for the image with unknown sparsity.

From that related studies, authors will be designed and analyze the influence of Compressive Sampling watermark on video watermarking based on Reed Solomon Code and Discrete Sine Transform (DST) using Singular Wavelet Transform (SWT), Singular Value Decomposition (SVD), and Orthogonal Matching Pursuit (OMP) reconstruction.

II. METHODOLOGY

A. Video Watermarking

Basically, video is the arrangement of several frames, and each frame is seen as a still image. Therefore, most of the methods of image watermarking can be applied to video watermarking. Watermarking of multimedia documents in the form of video can involve several watermarking techniques such as watermarking of image and audio. In doing of video watermarking, somethings that need to be considered are the robustness on compression process, geometric changes or cutting frames, the accuracy of frames coding without visual artefact, and must pay attention to the runtime or the speed performance of the video produced. Embedding the watermark of video watermarking is done in motion part or motionless. In its use, watermarking consists of two types, there are identical watermark and independent watermark. In order to avoid removal watermarking by an unauthorized person, then the embedding of the watermark is using the identical watermark in frame motionless watermarking section. Frame motionless watermarking is a technique for embed information into an audio file so the other people do not realize the additional information. Watermark is a good solution to protect from copyright of media by embedding data that only the owner knows [7].

B. Discrete Sine Transform

Synchronization of the Discrete Sine Transform (DST) is similar to Discrete Fourier Transform (DFT). DST states the time domain function or signal in sinusoidal quantities with differences in frequency and amplitude. DST is a class of sets of matrices that represent signals or functions [8]. Primarily, DST is used to solve partial differential equations with the spectral method in mathematics, and for signal compression in digital image processing or speech processing [1]

DST from one signal dimension or function $x(n)$, with $0 \le n \le N-1$, which is defined according to the following equation,

$$X(k) = DST\ [x(n)] \triangleq \sqrt{\frac{2}{N+1}} \sum_{n=0}^{N-1} x(n) \sin\left[\frac{\pi(k+1)(n+1)}{N+1}\right] \quad (1)$$

Equation 2 can be written in matrix notation as

$$x = Ax \quad (2)$$

with X is the vector $N \times 1$ which contains the coefficients of DST, A is the matrix of DST $N \times N$, and x is the vector $N \times 1$ which contains the input signal coefficients. Equation 1 and 2 are called the analysis equation or forward transformation equations of DST. The $N \times N$ DST matrix is called the kernel of DST.

The inverse *Discrete Sine Transform* (IDST) of $X(k)$ is formulated by

$$x(n) = IDST\ [X(k)]$$

$$x(n) = \sqrt{\frac{2}{N+1} \sum_{k=0}^{N-1} X(k) \sin[\frac{\pi(k+1)(n+1)}{N+1}]} \quad (3)$$

with, $0\ x \le n, k \le N-1$.

IDST can also be computed in a matrix as,

$$x = A^{-1}X \quad (4)$$

C. Stationary Wavelet Transform

Stationary Wavelet Transform (SWT) is a wavelet transformation algorithm designed to overcome the shortcomings of the Discrete Wavelet Transform (DWT), namely the lack of translation invariance. Translation invariance can be achieved by removing the down-sampler and up-sampler in DWT and increasing the filter coefficient in the algorithm by a factor of 2j-1 at the j^{th} level. SWT is a scheme related to redundancy because the output of each SWT level contains the same number of samples as the input. So for N level decomposition, there is N redundancy in the wavelet coefficient [7].

D. Singular Value Decomposition

Singular Value Decomposition is a technique commonly used to decompose a matrix. With SVD, a matrix is decomposed into three matrix components, namely two orthogonal matrices and a diagonal matrix containing singular values. The main characteristics of SVD are [7]:

1. Singular value in the image has good stability so that when the image is given a little attack, the singular value in the image does not experience significant changes.
2. Image quality will not be affected even though there is a slight change to SVD.
3. The function of Singular Value is to represent the property of the image.

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If X is a matrix of size $M \times N$, then Singular Value Decomposition will decompose the matrix X to $X = USV^T$ [8-10].

E. Compressive Sampling

Cartesian-Polar Compressive Sampling (CS) is also known as Compressed Sensing, a signal processing technique to efficiently obtain and reconstruct signals. CS is also used for signal compression. CS has the following formula [2] [11], [12].

$$y = Ax + z \tag{5}$$

with $x \in R^n$ and A is the sensing matrix m × n which will give information about x, and z is an unknown error equation that is deterministic or stochastic. A must have the Restricted Isometry Property (RIP) property [2].

F. Reed Solomon Code

The Reed Solomon code was first discovered in the technical literature in 1960 by Irving S. Reed and Gustave Solomon. The Reed-Solomon Code is an algorithm that has been used extensively in the field of communication and electronic equipment. In electronic equipment, this code is used for CDs (Compact Discs), DVDs (Digital Video Discs), and Blu-ray Discs. 20 Reed Solomon codes are usually written in RS (n, k) with m -bit symbols. Where an encoder takes k symbol data and adds a check symbol to create a n code-word symbol. The Reed Solomon Code can correct up to as many error symbols in a code-word where $2t = n - k$. For a symbol with length m, the maximum length of the code-word (n) is $n = 2^m - 1$. The equation m is the length of the symbol, n is the total number of symbols in a code-word, $n - k = 2t$ is the length of parity and the error correction ability of RS (n, k) is as much as t symbol [5].

G. Orthogonal Matching Pursuit

OMP can estimate the magnitude of the non-zero coefficient of x by solving the least-squares error between orthogonal projections of x that has been recovered from the calculation of vector y. Calculation of CS yv watermarking includes k-spare, x, and L bit image watermarking v, then yv is reconstructed using the OMP algorithm [7].

III. VIDEO WATERMARKING MODEL

On the audio watermarking design is divided into four stages, the first is the watermark compression process, then the embedding process, followed by the extraction and finally the reconstruction process.

A. Watermark Compression using CS

The watermark compression process in this study uses CS based on double transformation, namely DST. Watermark as the initial input of the process is given the RS code bit as the sender to arrive at the RS Code decoding. Then the DST transformation is used to get the frequency coefficient value. The result of this transformation is a sparse signal that will be a compressed signal. The compression process occurs in a measurement process where the sampling value of a sparse signal is reduced to a smaller matrix size according to the size of the matrix A. Matrix A is a measurement matrix. Matrix A is randomly generated. The process of watermark compression can be seen in Fig. 1.

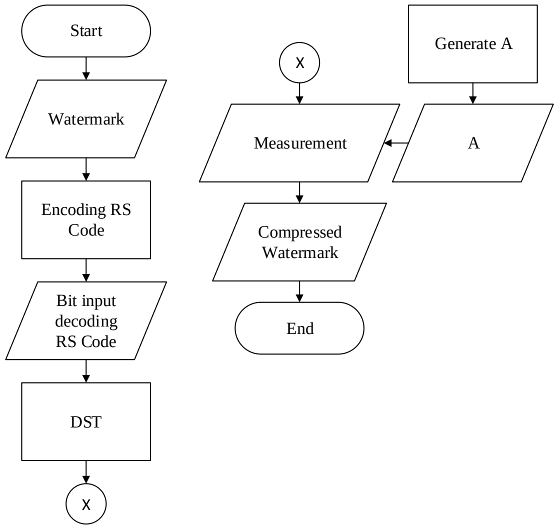

Fig. 1. The process of watermark compression using CS.

B. Proses Embedding

The embedding process aims to insert the compressed watermark resulting from the CS process into the host frame of the video. This process uses SWT and SVD methods. The SWT process produces four sub-bands, namely LL, LH, HL, and HH. Then one of the four sub-groups is selected for the SVD process. The results of the SVD process are three matrices namely U, S, and V. Compressed watermarks will produce U, Sw, and V from the SVD and sub-band results will produce U_{host}, S_{host}, and V_{host}. The process of inserting a watermark into the frame is done by adding S_w, which is multiplied by the ratio value that produces the S' to the frame. Furthermore, to get the results of the sub-band the inverse SVD process from S', U, and V. The last process to get the frame that has been inserted with a compressed watermark is inverse SWT.

The insertion technique using SVD is a non-blind watermarking technique so that the extraction process requires S_{host} values. The S_{host} matrix which is a singular value from the compressed watermark matrix needs to be saved to a key. The same is needed for the U and V values of the SVD results for the compressed watermark so that the values of U and V are also saved to the key. The embedding process that has finished produces two output outputs, namely the watermarked frame and key. Embedding process can be seen in Fig. 2.

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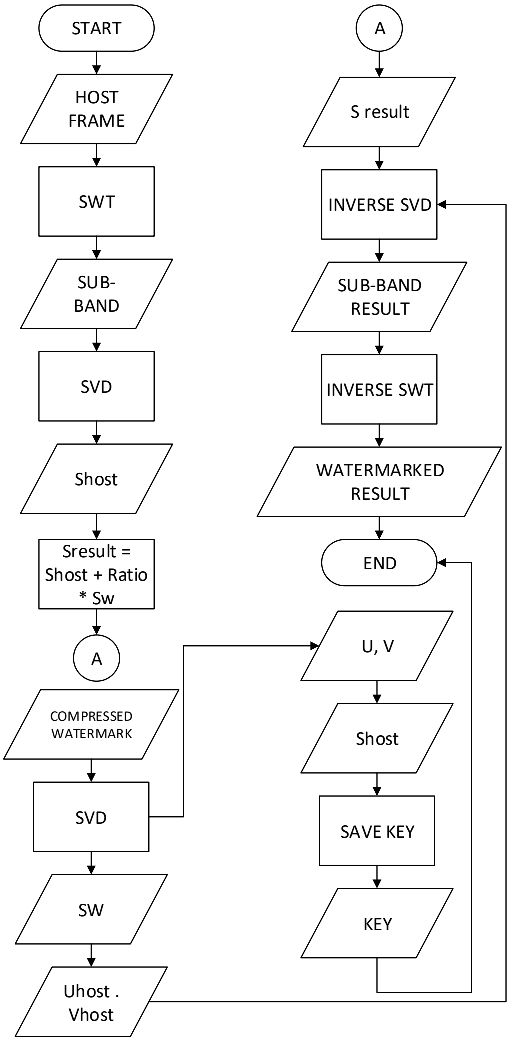

Fig. 2. Embedding process.

C. *Extraction Process*

The extraction process aims to regain the compressed extraction, which is the same signal as the compressed watermark produced by CS. The input of this process is a frame and key watermark. Basically, the Extraction process is the same as the embedding process. There are SWT and SVD. But the difference is in the process of getting S_w by doing the calculation shown in Fig. 3. S_{host} is obtained from the key. After getting the S_w back, then the SVD inverse process is performed to get the results of the compressed extraction. The inverse SVD process requires the U and V matrices obtained from the key.

D. *Reconstruction Process*

The last process to get a watermark again is the reconstruction process. This process aims to reconstruct the signal obtained from the signal results from CS measurements or measurement sampling. In this study, the signal to be reconstructed is a sparse signal. The sparse signal is the result of a DST transformation from a watermark and measurement sampling to a compressed watermark.

This study uses the OMP method for signal reconstruction methods. Compressed watermark will be the result after the OMP reconstruction process, this result is called DST inverse. The bits that have been sent through the encoding process in the compressive sampling process will be entered and checked again if there are still bits that are error or not. If there are still bits that are error, then decoding the RS Code is responsible for correcting and replacing the error bits to be correct. The reconstruction process can be seen in Fig. 4.

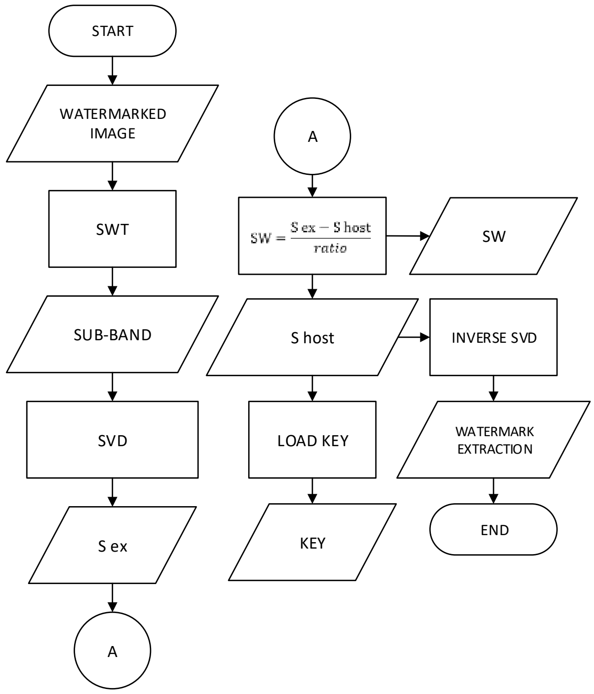

Fig. 3. Extraction process.

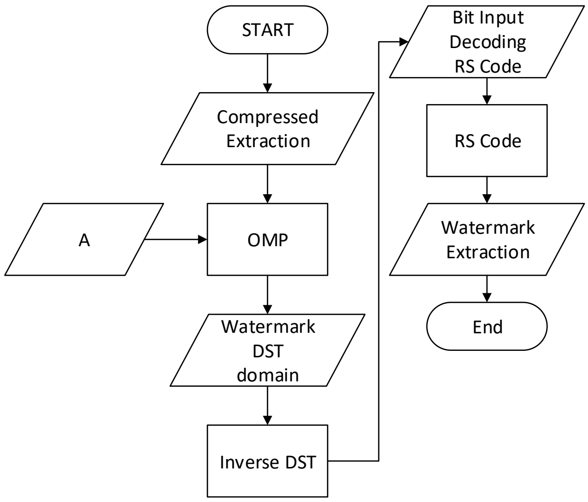

Fig. 4. Reconstruction process.

IV. VIDEO WATERMARKING MODEL

The message used in this test is a black and white image with a black background, each measuring 128 × 128, 256 × 256 and 512 × 512 pixels which consist of two colour layers, black as 0 bits and white layer as 1 bit then inserted into the image hosts, each of which has a 15-second video duration. The watermark image can be seen in Fig. 5.

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Fig. 5. Watermark Image.

A. Effect of Changes Parameters

When the colour layer testing has the results of the green layer with BER value of 0.09, PSNR value of 43,524 dB. Testing host image sub-band using sub-band HL with the best BER average value of 0.082. Level testing uses level 1 because it has a BER value of 0.083. The mother wavelet test uses dB because the value of BER is the best among the other dB or in other words BER which approaches the value 0 is dB. The best watermark in this test uses 512 × d512 because it has a BER value of 0.012 smaller than the other. The ratio used is a ratio of 0.4. The value of the measurement rate using a rate of 30% to 100% of the resulting BER is below 30%. The best BER value when the measurement rate is 1 with a BER value of 0.012. The results of the above tests are used for the next process, which is testing resistance with three types of attacks.

B. *Effect of Attack*

This test uses two types of attacks. There are Gaussian Noise Blur, Gaussian Noise Salt and Pepper and Rescaling.

a) Noise Gaussian

Table 1 shows the result of testing the system performance against Gaussian Noise interference. The test uses five sigma levels where the sigma level shows susceptibility to intensity. The three video data possessed are then inserted into the image selected as a watermark. An image that has the best results in each level of sigma used is the image with a resolution of 512 × 512 pixels and it can be concluded that image with 512 × 512 pixel resolution is resistant to Gaussian noise attacks.

b) Salt & Pepper

Table 2 shows that the obtained density value can make the system resistance to attacks and not experience the effect of damage. The BER value produced is always below 0.3, and the reconstruction results are better, but to get the CS reconstruction process takes a long time. The reconstruction results can be seen in the results of the reconstruction in Table 4. It can be concluded that the role of CS in this attack can make the performance better if seen from the value of BER produced.

c) Rescaling

Table 3 shows that the scale value obtained can make the system resilient to attacks and not experience the effect of damage. The BER value produced is always below 0.1, and the reconstruction results are better but to get the CS reconstruction process takes a long time. The results of the reconstruction can be seen in Table 4. It can be concluded that the role of CS in this attack can make the performance better if seen from the value of BER produced.

V. Conclusion

The video watermarking process uses the SWT-SVD method with the application of CS and RS Code produces an average BER value of 0.152 and the average value of PSNR 33.848 dB. Compressive sampling can be used as a compression method on watermarking techniques with a measurement rate above 50% resulting in a good performance with an average BER value of 0.060 and an average PSNR value of 34.535 dB. Watermark resistance is good if given a measurement rate above 70% and given several attacks by looking at the results of measurements that have been done, this is done by testing the Gaussian Noise Blur to get an average BER value of 0.131 and the average PSNR value of 28,789 dB, at Salt and Pepper, the average value of BER is 0.187, and the average value of PSNR is 28,789 dB. Rescaling testing gets an average value of BER of 0.097, and the average PSNR value is 36,151 dB. The effect of CS will be more pronounced if using a large original message image, but this makes the process of reconstruction time long if seen from the average value of the time of reconstruction when given an attack of 924,585 seconds.

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TABLE I. EFFECT OF GAUSSIAN ATTACK.

Sigma	MSE Embedding	PSNR Embedding	MSE Extraction	PSNR Extraction	MSE CS Reconstruction	PSNR CS Reconstruction	BER
1	39,684	34,298	193,564	25,296	155,707	26,208	0,077
2	39,549	34,295	195,604	25,261	155,716	26,208	0,149
3	39,593	34,305	196,313	25,242	155,717	26,208	0,146
4	39,298	34,317	192,876	25,324	155,716	26,208	0,144
5	39,185	34,327	192,192	25,345	155,715	26,208	0,141

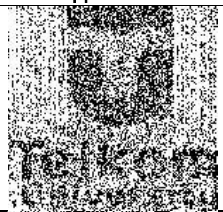
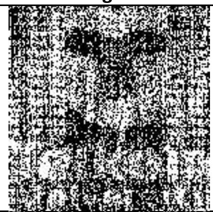
TABLE II. EFFECT OF NOISE SALT & PEPPER ATTACK

Noise Density	MSE Embedding	PSNR Embedding	MSE Extraction	PSNR Extraction	MSE CS Reconstruction	PSNR CS Reconstruction	BER
0,01	39,536	34,298	80.373	29,846	155,710	26,208	0.129
0,05	39,554	34,304	97.939	28,456	156,050	26,199	0.183
0,1	39,525	34,306	157.827	26,279	156,466	26.187	0.200
0,2	39,348	34,314	308.457	23,348	157,292	26.164	0.211
0,3	39,677	34,298	470.600	21,498	158,026	26.144	0.216

TABLE III. EFFECT OF RESCALLING ATTACK.

Scale	MSE Embedding	PSNR Embedding	MSE Extraction	PSNR Extraction	MSE CS Reconstruction	PSNR CS Reconstruction	BER
0,250	0,704	49,714	7,775	29,645	81,477	29,021	0,098
0,500	0,698	49,765	70,403	29,719	81,476	29,021	0,096
0,750	0,699	49,737	70,798	29,710	81,475	29,021	0,097

TABLE IV. RESULT OF RECONSTRUCTION PROCESS

Measurement Rate	The Image Result before attack	The Image result of Salt & Pepper Attack	The Image Result of Noise Gaussian Blur Attack	The Image Result of Rescaling Attacks.
40%				
50%				
60%				
70%