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An efficient audio watermarking scheme with scrambled medical images for secure medical internet of things systems

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Abstract

In recent times, the security of communication channels between healthcare entities in Medical Internet of Things (MIoT) systems becomes a significant issue to facilitate and guarantee the exchange of medical image and expertise securely. This paper presents an efficient audio watermarking scheme employing professionally Wavelet-based Image Fusion, Arnold transforms, and Singular Value Decomposition (SVD) for the secure transmission of medical images and reports in the MIoT applications. The essential consequence of the proposed scheme is to first syndicate two medical watermarks into a fused watermark to upsurge the payload of the inserted medical images. The fused watermark is then scrambled utilizing Arnold transform. Lastly, the Arnold fused watermark is inserted in the audio signal using the SVD algorithm following converting it into a 2D format. The choice of the Arnold transform for watermark is ascribed to settling robustness that skirmishes respective types of severe attacks. Several assessment metrics such as SNR, LLR, SNRseg, SD, and Cr are used to evaluate the audio watermarked signal and extracted watermarks The results reveal that the proposed audio watermarking scheme increases the capacity with more embedded medical images and security of implanted medical images transmission deprived of affecting the quality of audio signals, especially for IoT-based Telemedicine systems.

Keywords MIoT · Arnold transform · Audio watermarking · Wavelet fusion · Singular value decomposition · Medical image

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1 Introduction

In recent times, medical data transmission over the Internet poses various intimidations that cruelly affect its security and protection issues which demands a security mechanism such as Cryptography and a medical watermarking system to avoid illegal access by an unintended recipient. Cryptography is a security mechanism that protects data from access by an unauthorized person. But once data is decrypted, it can be distributed and duplicated illegally. Therefore, there is an essential need for another protection system after the data encryption process. Digital watermarking is the embedding process of any type of data in cover signal such as image, audio, and video to achieve several objectives such as copyright protection, medical safety, fingerprinting, broadcasting monitoring, integrity protection, and military. The combination between cryptography and watermarking produces a multi-level security system which gives us the features of both of them.

Recently, modern data telecommunication system has been theoretically valuable for their remarkable efficacy and quick communication of medical data over the Internet for Medical IoT systems. To design a secure medical watermarking algorithm in telemedicine systems, four essential requirements are mandatory which are robustness, security, capacity, and imperceptibility. These requirements can be satisfied by the following:

- A robust watermarking technique for watermark embedding and extraction such as Singular Value Decomposition (SVD) which resists many types of attacks due to Singular Values (SVs) has decent stability when the small perturbation is added to the audio signal, This makes the SVD a strong candidate for the design of efficient audio watermarking technique.
- The security can be achieved by using the Arnold algorithm which satisfies security and robustness.
- The capacity can be improved by embedding more information without affecting the quality of the audio signal by using the wavelet fusion algorithm.
- A trade-off among the audio watermarking algorithm requirements can be achieved.

In recent times, medical images significantly affect the efficient diagnosis process and investigation of serious diseases besides mitigating the misdiagnosis problems. Surplus, the stealing problem of medical identity and data has been a severe privacy concern in the telemedicine domain. In this paper, we presented an effective audio watermarking system for medical images in Telemedicine applications in a secure manner. The proposed scheme is constructed by a primary combination of two watermarks which are medical images and produces a particular fused watermark using the wavelet-based image fusion procedure, then Arnold transform is used and finally, the Arnold fused image is implanted in the cover audio signal.

The main paper's contribution is to provide a multi-level security system for medical image transmission over the MIoT system securely along with increasing the robustness and capacity without affecting the quality of the audio signal for authenticity, security, and protection of medical images over unsecured channels on the Internet. In summary, the proposed scheme has the following characteristics:

- The medical images are scrambled using Arnold transform beforehand embedding which upsurges the protection level for the implanted medical information before sending over insecure open network systems.

- The medical watermark images shouldn't worsen the original audio signal quality.
- The projected procedures for embedding and extraction of watermarks are vigorous. Also, these watermarks are capable of resisting several kinds of multimedia threats.
- Extra medical data can be embedded in the cover audio signal. This happened by the proposed watermarking that allows a satisfactory increase of watermarks in the watermarked audio signal.

The remaining of this work is prepared as the following: Section 2 delivers an outline of the elementary theories of watermarking systems, fusion method, and encryption techniques and also provides the relevant work. A comprehensive description of the proposed scheme is offered in Section 3. Section 4 offers the suggested multi-level security system and provides a high-level framework of the proposed multi-level security system for healthcare data transmission in telemedicine IoT applications. Section 5 gives the performance evaluation metrics that be able to be utilized in assessing the audio quality and extracted watermark images with also provides the investigational results examination of the planned scheme. Finally, the paper's summary and future scope are offered in Section 6.

2 Preliminaries and related work

2.1 Preliminaries

A review regarding wavelet-based fusion, Singular Value Decomposition, and Arnold algorithm is presented in this section.

2.1.1 Wavelet fusion

To combine two images into a particular image termed a fused watermark, it can be achieved by using the image fusion method as displayed in Fig. 1. This technique can save the better quality of the particular image by clarifying the information of an image where the resultant fused watermark can conserve the ultimate key features of the novel image.

2.1.2 Singular value decomposition (SVD)

The SVD is considered a mathematical analysis way to analyze the square and rectangular metrics which can be used for different image applications like image watermarking. For image watermarking applications, the SVD can be applied for extracting vital features of the SVD matrix of an image, then using these features, the watermark can be inserted in this

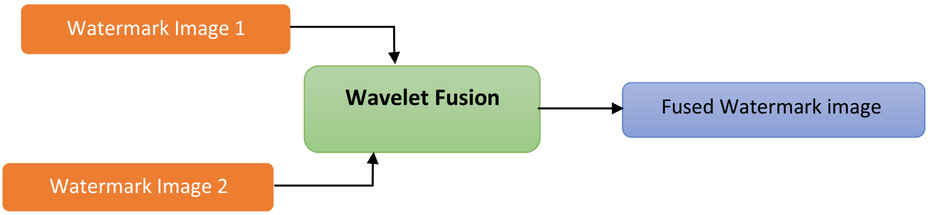


Fig. 1 The Process of Wavelet Fusion Approach

matrix without affecting the quality of watermarked image [23, 27]. From an image processing viewpoint, the SVD extracts important features as the following: (1). The SVs epitomize the intrinsic algebra properties of the image, and (2). The Singular Values (SVs) of the image are decent stability at the insignificant perturbation is added to an image, its SVs don't modify drastically that is vigorous in contradiction of severe attacks.

2.1.3 Arnold transform

Lately, numerous encryption approaches can be used for the encryption of digital images like common permutation and diffusion approaches. For applications of image processing, Arnold Transform the position of pixel not just be scrambled by coding the reiterative number of the progression but additionally diminishes the vital storage and communication spaces [5].

2.2 Related work

In telemedicine, medical images have been transmitted between two healthcare organizations for disease diagnoses. Still, medical image transmission over the Internet desires innovative security mechanisms such as digital watermarking. Image watermarking is a branch of multimedia watermarking techniques that can be employed for securing sensitive medical image communications transmission against severe attacks.

In [24], they suggested a watermarking system employing DWT, DCT, and SVD. The proposed system is verified against numerous attacks. In [12], they suggested a watermarking system using DWT, DCT, and SVD. In this system, the embedding step utilized the alteration of the singular values of the DCT coefficients of the host image with the watermark's singular values.

In [2], the authors introduced a watermarking technique based on DWT and SVD. In this work, the singular vector of the particular DWT sub-band of the cover image is altered with a binary watermark handling a false-positive problem. Authors in [21] provided a dual watermarking approach using DWT and SVD. In the implanting of the watermark phase, the watermark2 is implanted into the watermark1, and then the united watermark is embedded into the host image.

In [11], they provided a watermarking technique for medical images based on wavelet and BCH error-correcting code. Their technique is embedded watermarks of index, caption, signature, and reference at different sub-bands of DWT in the host image. In [15], they proposed a technique where it embeds the watermark into a particular sub-band of the natural image besides encrypting the watermarked image utilizing three cryptography methods. In [13], they projected a hybrid image watermarking technique by combining two grayscale images with the use of the wavelet fusion method. In [14], they anticipated a crossbreed image watermarking scheme that is based on fusing two grayscale images employing wavelet-based image fusion, and applying three-level DWT. Likewise, authors in [1, 7, 8, 10] presented more work regarding watermarking systems. In [1], they used reinforcement learning and blockchain to enable the IoMT system for healthcare workflows. In [19], they used Blockchain for Privacy Preservation and Fraud using Federated-Learning in IoMT System for Healthcare application. An efficient reversible watermarking system for achieving the key requirements of the watermarking system such as balancing capacity, imperceptibility, and robustness for medical color images [20].

It is determined that research work offered various works on image watermarking [6, 9]. Generally, there are rare contributions to multiple image watermarking techniques. Most of them have grave complications with watermark authentication and extraction. The conventional watermarking procedures have not attained acceptable watermarks and the extracted watermarks, particularly in the existence of multimedia attacks. Similarly, few audio watermarking techniques focus on employing implanted more watermarks with safeguarding the watermark with Arnold transform. Consequently, the existing research has robustness, and imperceptibility with low capacity.

With regard to the challenges of associated work in medical image watermarking on cover audio signals, the crucial role of this research is to offer an efficient audio watermarking scheme for secure medical image transfer. This scheme is based on Arnold transform, wavelet fusion, and SVD watermarking systems to secure two medical watermarks that can be implanted to reserve the key objectives of this work which are capacity, robustness, and imperceptibility efficiency.

3 Proposed audio watermarking scheme

The projected audio watermarking scheme is offered in this part, this scheme allows embedding multiple medical images into the cover audio signals and the extraction of them in an efficient manner. The procedures of medical watermarks embedding along with extraction are clarified as the following:

3.1 Medical watermark embedding

The watermark implanting procedure is revealed in Fig. 2. The algorithm works as the next:

1. a 2-D matrix (A matrix) is gendered from transforming the 1-D cover audio signal. The SVD is made on the A matrix.

$$A = U\ S\ V^T \tag{1}$$

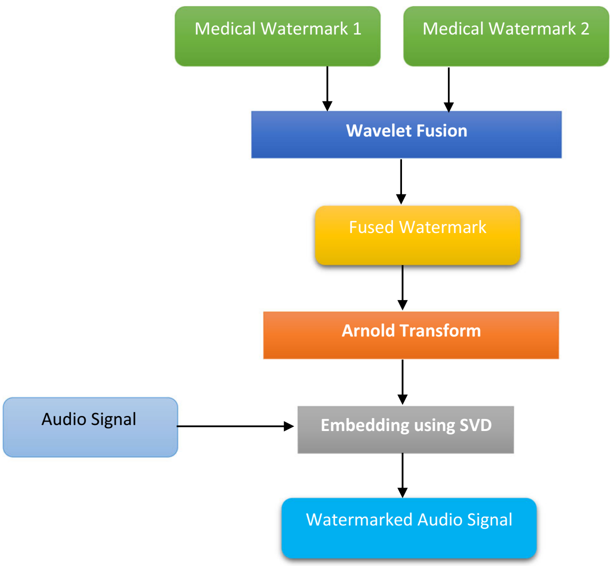


Fig. 2 Process of medical watermark images embedding

2. The medical watermark1 and watermark2 are combined by employing wavelet-based image fusion to produce a fused watermark (W matrix).
3. The Arnold transform is performed on the W matrix
4. The W matrix is mixed with the SVs of the A matrix.

$$D = S + \alpha\, W \tag{2}$$

5. To retain the audio unembroidered, a trivial estimate of α is selected (0.01).
6. The SVD is made on the new modified matrix (D matrix)

$$D = U_w\, S_w\, V^T{}_w \tag{3}$$

7. The A_w matrix in 2-D format (crypto-watermarked audio signal) is attained using matrix S_w

$$A_w = U\, S_w\, V^T \tag{4}$$

8. The crypto-watermarked audio signal (A_w matrix) is converted again into a 1-D format

3.2 Medical watermark extraction

The extracting procedure is revealed in Fig. 3. This works as the next:

1. a 2-D A^*_w matrix is transforming from the 1-D watermarked signal.
2. The SVD is made on the A^*_w matrix.

$$A^*{}_w = U^*\, S^*{}_w\, V^{*T} \tag{5}$$

3. The matrix contains the fused watermark calculated

$$D^* = U_w\, S^*{}_w\, V^T{}_w \tag{6}$$

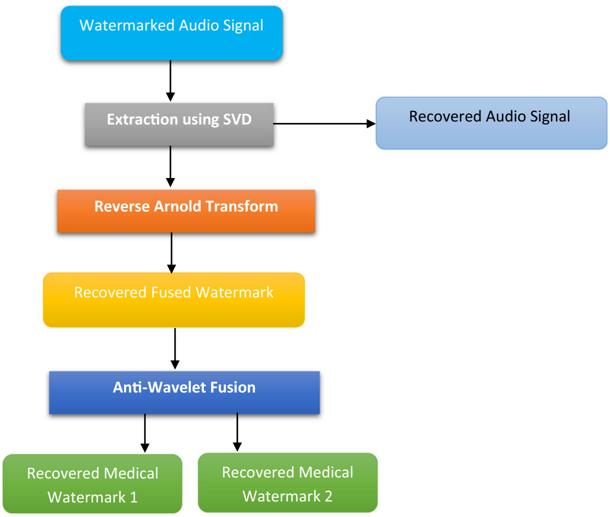


Fig. 3 Process of medical watermark images extraction

4. The conceivably fused watermark is gained

$$W^{*} = \left(D^{*} - S\right)/\alpha \tag{7}$$

5. The extracted watermark (W* matrix) is converted using the reverse Arnold transform.
6. Anti-fusion of the revere Arnold fused watermark to obtain medical watermark1 and watermark2 respectively.

4 High-level multi-level imagery transmission security framework in telemedicine systems

In last years, data security and guard for IoT-based medical systems is a perilous task in the medical sector for protecting patients' information from unauthorized access over unsecured channels on the Internet. Figure 4 offerings the overall projected Multi-Level imagery transmission security system for securing medical information in hospitals in the context of smart telemedicine services using hybrid cryptography and watermarking approaches. The proposed system is announced to provide a secure scenario for proficiently delivering medical images between remote entities in medical IoT systems.

The patients and healthcare staff from the medical entity1 (sender) secure important medical images utilizing the proposed audio watermarking scheme and transmit them to the storage cloud provider. The medical staff in the medical entity2 (receiver) retrieves the medical digital images from the storage cloud, thus restoring the secret images by using the proposed extraction scheme. The planned watermarking scheme safeguards high embedded information capacity, high confidentiality, robustness, and multi-level security for healthcare organizations in telemedicine services.

5 Experimental study

5.1 Assessment metrics

To evaluate the audio watermarked signal from the perceptual quality perspective, the next evaluation metrics are offered. Numerous methods for subjective and objective measurements are espoused to evaluate the quality of the audio signal [3, 4, 16–18, 22, 25, 26]. The objective measurements are used in this work for assessment purposes. Likewise, the correlation

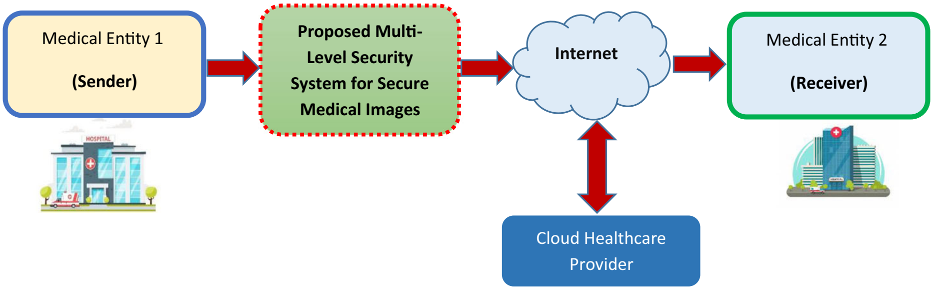


Fig. 4 A high-level illustration of the proposed multi-level security framework for remotely medical image Transmission and Exchange in MIoT Systems

coefficient is applied to calculate the intimacy of the reversed Arnold watermark to the initial watermark as well as medical watermark1 and watermark2.

5.1.1 Audio signal quality metrics

In this section, we will discuss the objective measures which are commonly separated into intrusive as well as non-intrusive procedures. Intrusive procedures are categorized into three major sets which are time domain, Linear Predictive Coefficients (LPC), and Spectral-domain metrics [3, 4, 16–18, 22, 25, 26].

- **Time Domain**

These metrics comprise both of Signal-to-Noise Ratio plus Segmental Signal-to-Noise Ratio that can be defined as the following:

a. ***Signal-to-Noise Ratio (SNR)***

The SNR is demarcated as follows:

$$SNR = 10\log_{10}\frac{\sum_{i=1}^{N} x^2(i)}{\sum_{i=1}^{N} (x(i)-y(i))^2} \quad (8)$$

x(i) is the host audio, y(i) is the watermarked audio, (i) is the sample index, then N is the overall samples in both host and watermarked audio.

b. ***Segmental Signal-to-Noise Ratio (SNRseg)***

The SNRseg is demarcated as follows:

$$SNRseg = \frac{10}{M}\sum_{m=0}^{M-1}\log_{10}\sum_{i=Nm}^{Nm+N-1}\left(\frac{x^2(i)}{(x(i)-y(i))}\right)^2 \quad (9)$$

M is the segments in the watermarked signal and N is the segment length.

- **Log-Likelihood Ratio (LLR)**

The LLR is defined as:

$$LLR = |\log\left(\frac{\overrightarrow{a}_x \overline{R}_y \overrightarrow{a}_x^T}{\overrightarrow{a}_y \overline{R}_y \overrightarrow{a}_y^T}\right)| \quad (10)$$

where $\overrightarrow{a}_x$ is the LPC coefficient vector (1, a_x(1), a_x(2),. ..,a_x(p)) for the cover audio $x[n]$, $\overrightarrow{a}_y$ is the LPC coefficient vector (1, a_y(1), a_y(2),. .., a_y(p)) for the watermarked audio $y[n]$, and $\overline{R}_y$ is the autocorrelation matrix for the watermarked audio. The closer the LLR to zero, the higher is the watermarked audio quality.

- **Spectral Domain(SD)**

The Spectral distortion (SD) depends on the assessment of the power spectrum of the host signal and the handled signal. The spectral distortion (SD) can be computed as follows:

$$SD = \frac{1}{M}\sum_{m=0}^{M-1}\sum_{i=Nm}^{Nm+N-1}\left|V_x(i) - V_y(i)\right| \tag{11}$$

Vx(i) is the spectrum of the host audio for a particular segment in the time domain, Vy(i) is the spectrum of the watermarked audio for the matching segment; N is the segment length and M is the segments number in the audio signal. The smaller the SD, the better the watermarked audio quality.

5.1.2 Image quality metrics

- ***Correlation Coefficient (Cr)***

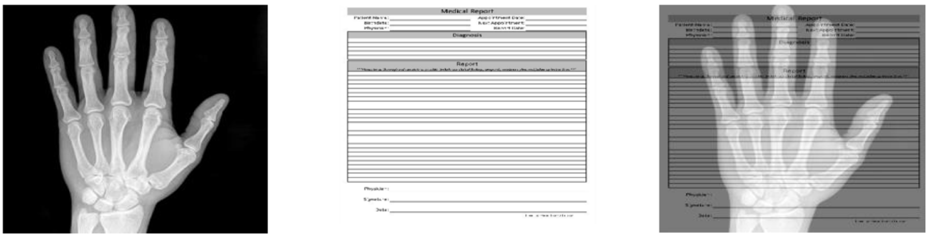
The C_r is to calculate the closeness of the host image to the modified one. In the perfect circumstance, the C_r ought to be 1. Nevertheless, this is not conceivable for the extracted fused image, consequently, a close value to 1 is desirable.

$$\mathrm{Cr} = \frac{\sum_m \sum_n \left(Xi - X'\right)\left(Yi - Y'\right)}{\sqrt{\left(\sum_m \sum_n \left(Xi - X'\right)^2\right)\left(\sum_m \sum_n \left(Yi - Y'\right)^2\right)}} \tag{12}$$

X’ and Y′ represent respectively the average values of the host and watermarked images.

5.2 Results exploration and analysis

Several experiments are executed to evaluate the planned scheme which is implemented using MATLAB with medical watermark1 and medical report watermark 2 images combined by using wavelet fusion to construct the fused watermark image as displayed in Fig. 5. The SVD watermarking method is used for inserting the fused watermark in the Handel audio signal which is used as the cover signal in the proposed system. Figure 6 shows the fused and Arnold fused images that were used in the experiments in this paper.

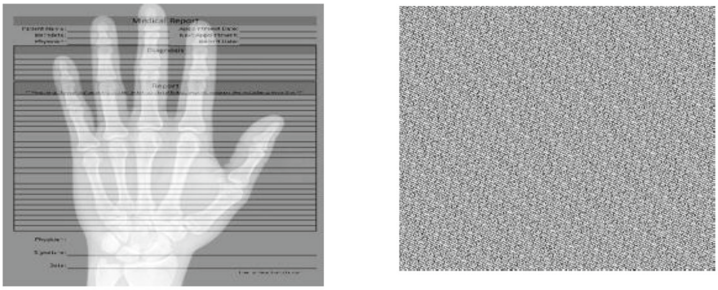


(a) Medial Watermark 1

(b) Medial Report Watermark 2

(c) Fused Watermark

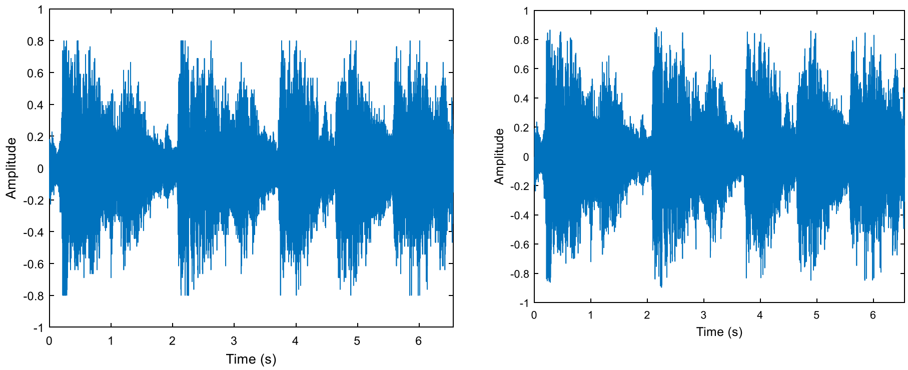
Fig. 5 Original watermark images



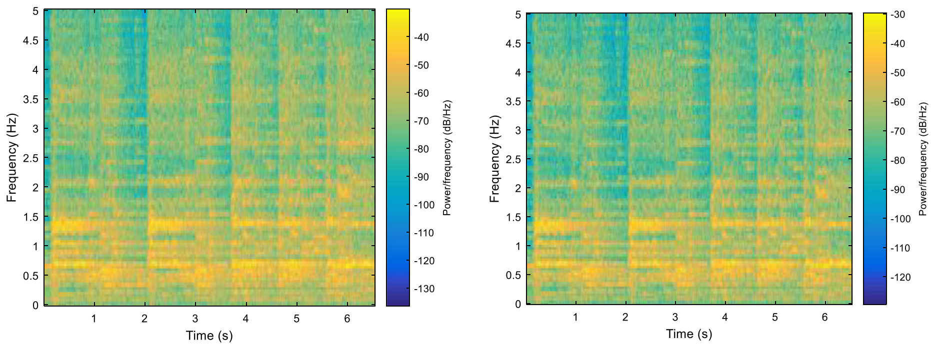
(a) Fused Watermark (b) Arnold Fused Watermark C_r= 0.0011

Fig. 6 Fused and Arnold Fused watermark images

To test the accomplishment of the projected audio watermarking scheme, the simulation results are carried out in this part. In all tests in this work, the aforementioned audio quality metrics are used for the assessment of the watermarked signal quality, and the correlation coefficients are used to calculate the closeness of the retrieved to the original image.

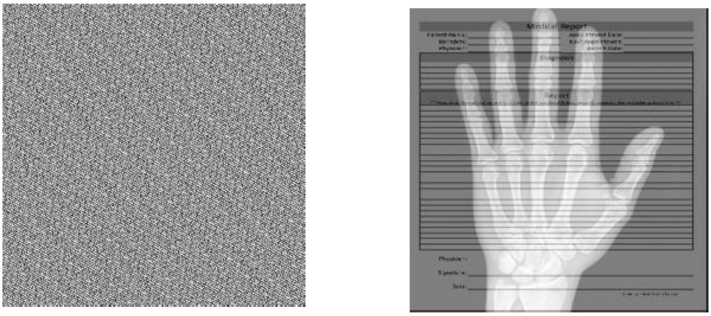


(a) Host audio (b) Watermarked audio



(c) Host audio spectrogram (d) Watermarked audio spectrogram

Fig. 7 Host and Watermarked audio



(a) Arnold fused watermark C_{rd}=0.0011

(b) Reversed Arnold fused watermark C_{re}=1

Fig. 8 Extracted fused watermark without attack

In the proposed scheme, Arnold transform is used to transform the fused watermark to enhance the security level of implanted images. Then, the algorithms of embedding, as well as extraction, are achieved in the absence of the attack. Figure 7 shows the original and watermarked audio signals. The correlation coefficient among the extracted and the original one reveals that the watermark is seamlessly restored in the absenteeism of attacks as shown in Figs. 8 and 9.

To study the robustness of the proposed system, three different experiments are performed as follows: In the First experiment, the robustness of the proposed scheme is analyzed in the occurrence of the attack of additive white Gaussian noise (AWGN) on the watermarked audio.

The results of watermark embedding and extraction of this attack are shown in Figs. 10 and 11. In the second experiment, the robustness of the proposed scheme is considered in the existence of a cropping attack on the watermarked audio signal. The results of watermark embedding and extraction of this attack are shown in Figs. 12 and 13. In the third experiment, the robustness of the proposed scheme is deliberated in the existence of attack namely wavelet compression on the watermarked audio signal. The results of watermark embedding and extraction of this attack are displayed in Fig. 14 and Fig. 15.

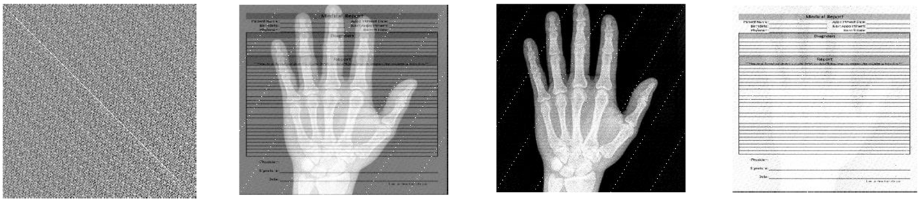
Table 1 shows the proposed system with various audio quality evaluation metrics in the absence and presence of severe attacks such as noise attack, cropping attack, and wavelet compression attack, respectively. Furthermore, the correlation is used to assess the closeness of

(a) Extracted Fused Watermark C_{re}=1

(b) Medial Watermark 1 C_{r1}=1

(c) Medial Report Watermark 2 C_{r2}=1

Fig. 9 Extracted watermark without attack

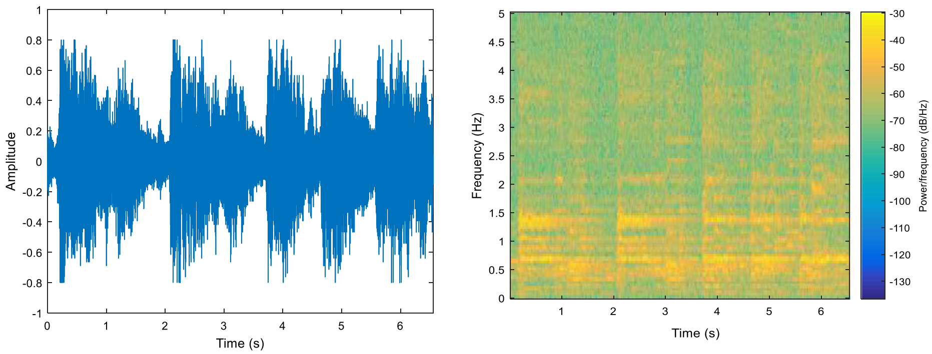


(a) Arnold fused watermark C_{rd}= 0.0033 (b) Fused Watermark C_{re}= 0.9328 (c) Medial Watermark 1 C_{r1}= 0.9856 (d) Medial Report Watermark 2 C_{r2}= 0.9744

Fig. 10 Extracted watermark with noise attack

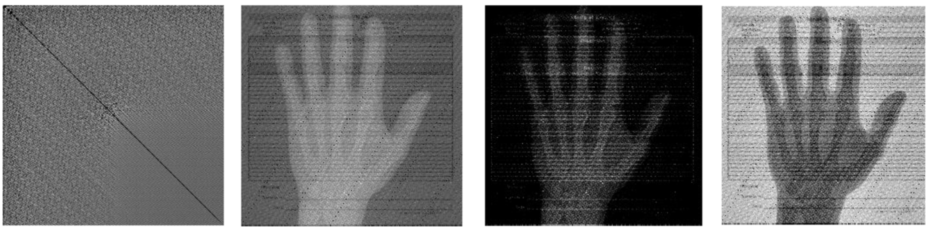
the reversed Arnold watermark to the initial watermark as well as medical watermark 1 and watermark 2.

Tables 2 and 3 show different quality metrics for the proposed audio watermarking scheme in the existence of both noise and wavelet compression attacks, respectively. Similarly, Fig. 16 to Fig. 17 show the correlation coefficient of extracted watermarks from the proposed audio watermarking scheme in the presence of the noise attack, and the wavelet compression attack. Values them, it is clear that an SNR value close to −25, decreases the recognition probability of the watermark while when the value becomes close to +25, increases the recognition proba-



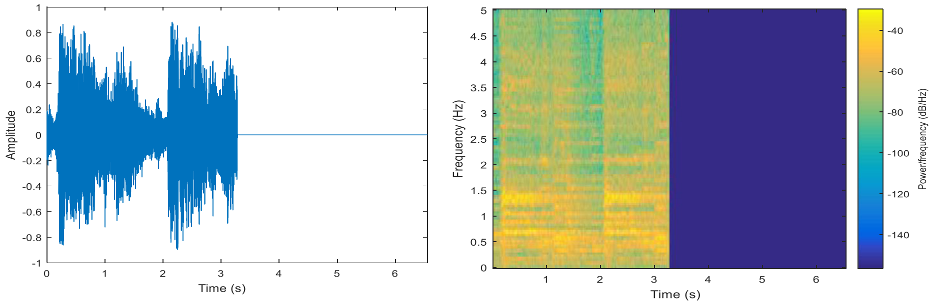
(a) Noisy watermarked audio (b) Noisy watermarked spectrogram

Fig. 11 Noisy watermarked audio



(a) Arnold fused watermark C_{rd}= 0.0111 (b) Fused Watermark C_{re}= 0.1641 (c) Medial Watermark 1 C_{r1}= 0.1641 (d) Medial Report Watermark 2 C_{r2}= 0.7054

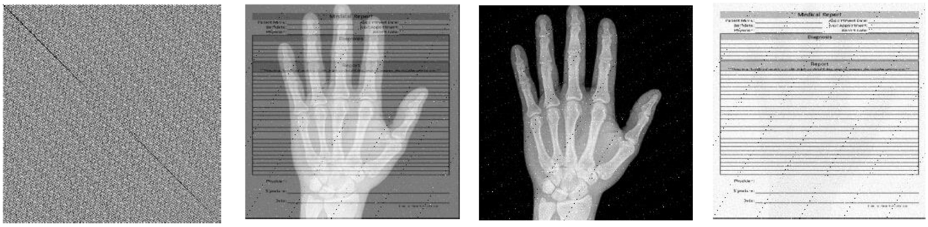
Fig. 12 Extracted watermark with cropping attack



(a) Cropped watermarked audio

(b) Cropped watermarked spectrogram

Fig. 13 Cropping attack-based watermarked audio



(a) Arnold fused watermark C_{rd}= -6.0601e-04

(b) Fused Watermark C_{re}= 0.9335

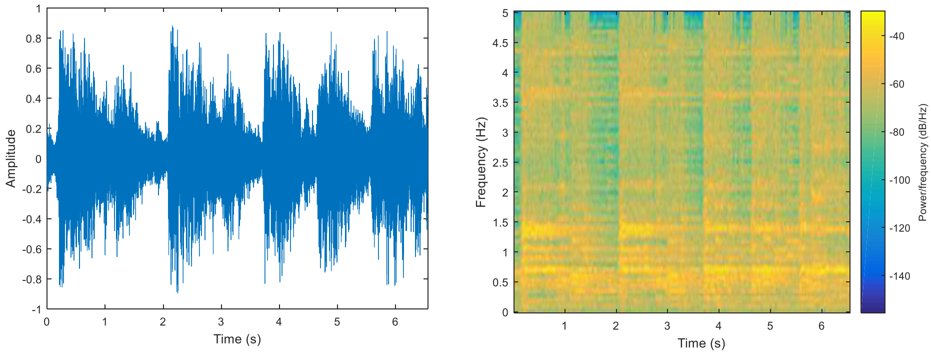
(c) Medial Watermark 1 C_{r1}= 0.9924

(d) Medial Report Watermark 2 C_{r2}=0.9526

Fig. 14 Extracted watermark with compression attack

bility of the watermark. For the compression attack, it is obvious that as the threshold value is closed to zero, increases the detection probability of the watermark.

The proposed audio watermarking scheme is tested and evaluated with single and two watermark images as tabulated in Table 4. Finally, a comparative evaluation stuck between the proposed scheme and the traditional SVD scheme is demonstrated in Table 5 where the results of the suggested scheme are better than the conventional SVD scheme. The overall experimental results validate that the proposed audio watermarking scheme can mutually transmit the



(a) Compressed watermarked audio

(b) Compressed watermarked spectrogram

Fig. 15 Compression attack-based watermarked signal

Table 1 Numerical evaluation metrics for the proposed audio watermarking scheme

	Without attack	Noise attack	Cropping attack	Compression attack
SNR (dB)	22.4069	13.8365	3.0159	11.6431
LLR	0.0314	0.0794	0.2910	0.0807
SNRseg (dB)	21.6021	13.7924	2.9828	11.6032
SD (dB)	1.4225	3.6300	11.7609	4.5777
C_{re}	1	0.0033	0.0111	−6.0601e-04
C_{rd}	1	0.9328	0.1641	0.9335
C_{r1}	1	0.9856	0.7054	0.9924
C_{r2}	1	0.9744	0.3537	0.9526

medical images by embedding them using wavelet fusion as well as increase security levels by using Arnold transform as second-level security. Furthermore, increasing embedding capacity into two medical images can happen with less effect on the perceptibility of audio signals. The proposed system was evaluated by taking into consideration the tuning of embedding strength in the absence or presence of severe multimedia attacks. The limitations of this work are that we applied only grayscale images.

Table 2 Evaluation results of the proposed scheme with different SNR values

SNR(dB)	C_{rd}	C_{r1}	C_{r2}	SNR (dB)	LLR	SNRseg (dB)	SD(dB)
−25	0.1874	0.6387	0.3607	−25.4565	0.3930	−25.4910	58.5550
−20	0.1941	0.6989	0.3571	−20.5006	0.3789	−20.5400	47.3832
−15	0.2060	0.7685	0.3606	−15.4735	0.4274	−15.5045	36.3587
−10	0.2281	0.8328	0.4001	−10.4950	0.3737	−10.5344	26.5082
−5	0.2695	0.8838	0.5151	−5.4594	0.3176	−5.4920	18.5116
0	0.3475	0.9178	0.6715	−0.4970	0.2936	−0.5296	12.8356
5	0.4988	0.9513	0.8080	4.4466	0.2044	4.4120	8.7907
10	0.7386	0.9724	0.9112	9.3172	0.1218	9.2837	5.6972
15	0.9361	0.9860	0.9766	13.8865	0.0828	13.8486	3.6120
20	0.9894	0.9916	0.9927	17.7106	0.0673	17.5959	2.3977
25	0.9987	0.9986	0.9980	20.3404	0.0328	20.0054	1.8106

Table 3 Assessment results of the proposed system with various T values

T	Quality Evaluation Metrics						
	C_{rd}	C_{r1}	C_{r2}	SNR (dB)	LLR	SNRseg (dB)	SD(dB)
0	1	1	1	22.4069	0.0314	21.6021	1.4225
0.1	0.9975	0.9982	0.9936	18.9585	0.0359	18.7877	2.1015
0.2	0.9788	0.9953	0.9784	14.2111	0.0709	14.1584	3.5123
0.3	0.9335	0.9924	0.9526	11.6431	0.0807	11.6032	4.5777
0.4	0.8484	0.9813	0.8907	10.2653	0.1184	10.2168	5.2888
0.5	0.7363	0.9590	0.8072	9.5420	0.1138	9.4771	5.6978
0.6	0.6320	0.9176	0.7019	9.2077	0.1183	9.1400	5.8916
0.7	0.5655	0.8839	0.6333	9.0448	0.1207	8.9787	6.0010
0.8	0.5372	0.8676	0.6043	8.9836	0.1218	8.9135	6.0399
0.9	0.5220	0.8571	0.5875	8.9551	0.1233	8.8836	6.0597

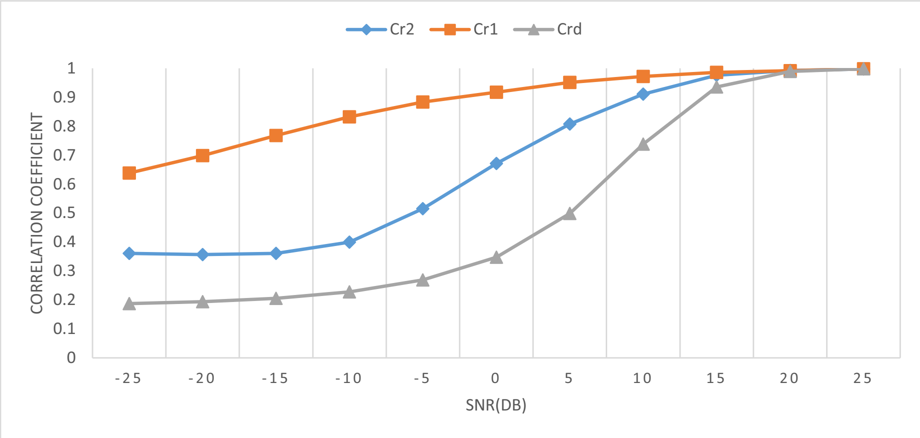


Fig. 16 Correlation among the extricated watermark and the initial watermark vs. the SNR for the proposed scheme in the existence of a noise attack

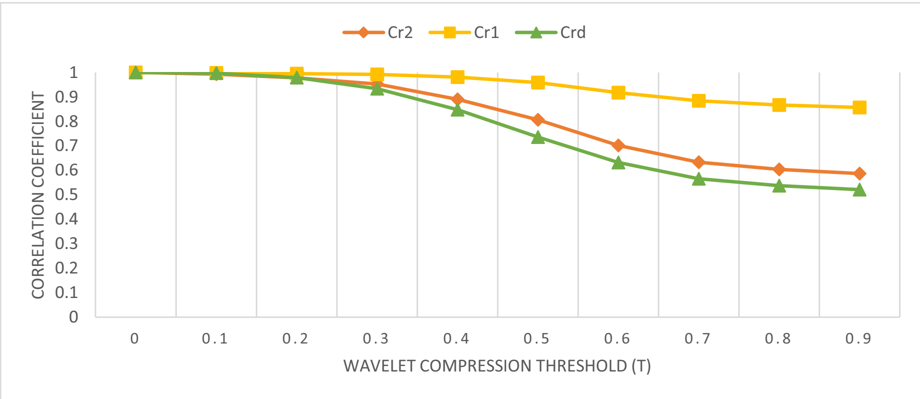


Fig. 17 Correlation among the extricated watermark and the initial watermark vs. the compression threshold for the proposed scheme in the existence of a compression attack

Table 4 Results of the proposed scheme with single and two watermark images

Metric	Single Medical Watermark				Two Medical Watermarks			
	Attack				Attack			
	Without	Noise	Cropping	Compression	Without	Noise	Cropping	Compression
SNR (dB)	−34.9007	−35.0396	−31.8145	−34.6248	22.4069	13.8365	3.0159	11.6431
LLR	0.2243	0.1866	0.2945	0.2067	0.0314	0.0794	0.2910	0.0807
SNRseg(dB)	−35.1352	−35.2611	−32.1059	−34.8492	21.6021	13.7924	2.9828	11.6032
SD(dB)	80.3559	80.6729	73.0526	79.7610	1.4225	3.6300	11.7609	4.5777
C_{rd}	1	0.9992	0.9874	0.9995	1	0.9328	0.1641	0.9335
C_{r1}	–	–	–	–	1	0.9856	0.7054	0.9924
C_{r2}	–	–	–	–	1	0.9744	0.3537	0.9526

Table 5 A comparison between the proposed audio watermarking Scheme and traditional SVD audio watermarking

Metric	Traditional SVD Scheme (SVD with single medical watermark)				Proposed Scheme (SVD, wavelet fusion, and Arnold transform with two medical watermarks)			
	Attack				Attack			
	Without	Noise	Cropping	Compression	Without	Noise	Cropping	Compression
SNR (dB)	−34.9409	−35.0712	−31.6769	−34.8002	22.4069	13.8365	3.0159	11.6431
LLR	0.4871	0.3939	0.4562	0.4900	0.0314	0.0794	0.2910	0.0807
SNRseg (dB)	−36.3448	−36.3957	−33.1407	−36.1334	21.6021	13.7924	2.9828	11.6032
SD (dB)	78.3298	78.8369	70.2985	78.1212	1.4225	3.6300	11.7609	4.5777
C_{rd}	–	–	–	–	1	0.9328	0.1641	0.9335
C_{r1}	1	0.9886	0.9994	0.9984	1	0.9856	0.7054	0.9924
C_{r2}	–	–	–	–	1	0.9744	0.3537	0.9526

From Table 6, the significance of the projected scheme is quite obvious. This scheme is an effort to use a multipurpose regulating watermarking that can deliver entirely kinds of watermarking aim with bit conciliation in requirements like capacity.

6 Conclusion and future scope

This paper proposed an efficient and robust audio watermarking scheme using Wavelet Fusion, Arnold transforms, and Singular Valued Decomposition (SVD) for medical images in MIoT applications. In this scheme, two medical watermarks are merged into a particular watermark named fused watermark employing the wavelet-based image fusion procedure to improve the capacity of the embedded medical information. Then, Arnold transformed used to encrypt the fused watermark. Finally, the Arnold fused watermark is implanted in the audio signal to improve the security of the embedded information. The simulation results prove that watermark embedding does not depreciate the audio signal. It is clear through the results that wavelet fusion is an efficient algorithm to combine two images, in addition, to improving the quality of the scrambled image. The proposed audio watermarking scheme can satisfy the

Table 6 A comparative analysis with the earlier approaches

Work	Cover Signal	No of watermarks	Watermarking Technique	Encryption	Wavelet Fusion	Increased Capacity
[3]	Audio Signal	One Image	SVD	Chaotic	Yes	No
[6]	Audio Signal	One Image	SVD	DES and Chaotic	Yes	No
[9]	Audio Signal	One Image	LSB	AES, RC6, and MD5	Yes	No
Proposed Scheme	Audio Signal	Two Gray Medical Images	SVD	Arnold Transform	Yes	Yes

audio watermarking requirements without affecting the quality of the audio signal with the ability to detect and extract the watermark in the occurrence of severe multimedia attacks. In the future, we plan to use other watermarking approaches like DCT, and DWT and use the color image within the embedding process by employing other encryption algorithms. Likewise, we utilize the proposed scheme can be extended work for the secure transmission of COVID-19 Patient's data such as X-ray images over unsecured channels on open networks such as the Internet to guarantee their privacy and safety.

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Data availability The data is available up to a request from the author.

Declarations

Competing interests The author(s) declare(s) that they have no competing interests.

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