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Monitoring of Epileptical Patients Using Cloud-Enabled Health-IoT System

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ABSTRACT

The health Internet of Things (IoT) lays the basis for emergency care for epileptic patients. The security of data transmission in the network calls for a robust monitoring technique. This paper proposes a monitoring model for epileptic patients, using a cloud-based health IoT system. To ensure the data security, watermarking was carried out through discrete wavelet transform-singular value decomposition (DWT-SVD), followed by short time Fourier transform (STFT). The proposed watermarking scheme, which is based on STFT and DWT-SVD, was verified on electroencephalography (EEG) data of class Z and class S. The results show that our scheme achieved a good watermarking performance, with a peak signal-to-noise ratio (PSNR) of 35.25 and a signal-to-noise ratio (SNR) of 31.32.

1. INTRODUCTION

Epilepsy is a brain related disorder affecting a huge population in this world. Seizures due to epilepsy are mainly because of abnormality in the brain. As epileptic patients may face different types of problems like accidents, injuries, which may cause of even death also, therefore they require special care to avoid all these and it is possible with the use of cloud based Health-IoT system. Such systems are not only able to provide real time data processing but users may get faster and quicker response from health experts. The internet of things (IoT) basically is interconnection of networks which includes various types of sensors, wearable devices, things like smartphone, Bluetooth etc. several communication techniques that may help for numbers of applications using its processing ability and lower complexity of system [1]. In the field of healthcare, use of cloud based IoT provides an added advantage of large storing capacity, which makes possible a smart healthcare system. Health-IoT provides environments for information exchange and monitoring of patients, even remotely with lower cost and superior quality of service [2].

For the monitoring of epileptic patients Health-IoT may play great role. As during epileptic seizures, there is lot of chances that he may not able to move or with some critical condition Health-IoT system is able to collect EEG (electroencephalogram) data from patients using sensors or wearable devices and can be transmitted with the IoT use of devices. EEG data may be of very large size that may be stored in cloud server, from where experts may able to access the information and may suggest & provide service to the patients in quicker way [3]. Health-IoT systems with cloud are able to provide service with high accuracy and low cost. Epileptic patients may suffer with jerks in their body and may loss his stability, which affects his personal life, social life as well as economic state. If he may able to detect this problem on time then it can be cured with proper suggestion and treatment [4]. Cloud based Health-IoT system could solve this problem with use of smart devices. For epileptic patients EEG data may be collected using wearable devices, these collected signals may be transmitted with the use of IoT devices to the cloud, where it can be stored or enhanced for further use [5]. In cloud environment, with these EEG data features can be extracted and classification can be performed on the basis of these features. Now system will be able to detect the accuracy of classification of EEG data and epilepsy can be predicted. The stored information further can be transmitted to receiver end / hospital or experts may able access this information from cloud. On the basis of these information experts may give feedback as suggestion or in case of emergency service can be provided.

This paper is organized in following manner. In section II some of the related work has been presented. Further in section III, a model for cloud based Health-IoT system has been proposed. Section IV presents methodologies and work done for this paper, which describes STFT and DWT-SVD based watermarking scheme for EEG data. Thereafter in section V and VI presents EEG dataset and performance of watermarking as a result respectively. At last in section VI conclusion and future work has been mentioned.

2. RELATED WORK

This paper mainly deals with monitoring of epileptical patients using cloud based Health IoT system and focused on transmission EEG data in secured way to the cloud for that DWT-SVD based watermarking method has been used. With the use of sensors, wearable devices or interconnected devices in Health-IoT network, patient's EEG data can be acquired in real time. For the monitoring of remote located patients a system is proposed by authors using cloud computing and web series [6]. There are several challenges for modeling a cloud based Health-IoT system, with this issue opportunity and challenges for patients health monitoring using IoT platform has been presented by authors [7]. Use of cloud base IoT in health field is an interesting one which provides a huge range of evolving applications, in which patients monitoring is a kind of revolution. This paper deal with epileptical patients monitoring Health-IoT system, where along with users, numbers of experts are connected in a network and user may have the provision of second opinion too [8]. For maintaining electronics health record in an IoT based network a brief discussion is given by authors [9]. To save patients data from hacker or from being misused information has been mentioned by authors [10]. In cloud based Health-IoT system, proper use of data acquiring, handling and transmission has been presented [11]. Cloud assisted industrial internet of things (IIoT) enabled framework has been proposed by authors for health monitoring [12]. Health related data accessing in IoT based system has also been proposed by researchers [13].

For transmission in secured way, architecture of network for healthcare model has been proposed by authors [14]. For monitoring of patients and assessment of health condition automatically, RFID based system model has been presented [15]. Discussion on security of data from various types of threats has been presented by author, which deals with prevention of information loss, misuse of patient data etc. [16]. For communication from the various wearable devices to cloud, affective interaction through wearable computing and cloud technology has been presented here [17]. For securing image data algorithm based on DWT and SVD has been presented [18]. An algorithm based on Lifting Wavelet Transform (LWT) used to provide high security in various application of telemedicine [19]. Another robust and indiscernible watermarking algorithm proposed by author is LWT-SVD [20]. A robust watermarking algorithm based on DWT-DCT-SVD and chaotic encryption has also been presented by researchers [21].

For the monitoring of epileptical patient's EEG data can be collected by placing electrodes (wearable device) over the scalp. Pre-processing is required for collected EEG data to remove unwanted component. Now the data will be ready for transmission using IoT devices to cloud. In this paper DWT-SVD based watermarking has been done to secure the patients data, which will be store in cloud for further feature extraction and classification purpose. On the basis of classification accuracy experts may able to predict epileptic seizures and suggest to patients about medicine and their dosage, even in case of emergency various health related service can be provided by service provider. To perform watermarking of EEG data first of all time domain EEG data need to be converted in time frequency domain using suitable method, then watermarking can be performed.

3. PROPOSED MODEL FOR CLOUD BASED HEALTH-IOT SYSTEM

Cloud based Health-IoT system has made a great change in the field of healthcare sector.

With this, users will be able to get economical and quality service for the monitoring and care of patients. With amalgamation of huge number of devices, sensors, cloud computation techniques, way of communication has revolutionized health industry.

Data flow model has been presented in Figure 1, it shows in what manner epileptic patient information / EEG data are acquired and processed securely through communication gateways to the cloud. This model represents that mentioned functions like pre-processing, feature extraction and classification are perform in the cloud itself. At receiver end hospitals / experts may access this information and on the basis of classification accuracy they may detect epileptic seizures. According experts may suggest for treatment, medicine or can ask for service to service providers in case of emergency. Performance of Health-IoT system mainly related to evolution of cloud computation techniques and analysis of EEG data. As much as technology grows success rate of cloud based Health-IoT system will also improve. For communication between machine-to-machine, a survey has been presented briefly [22].

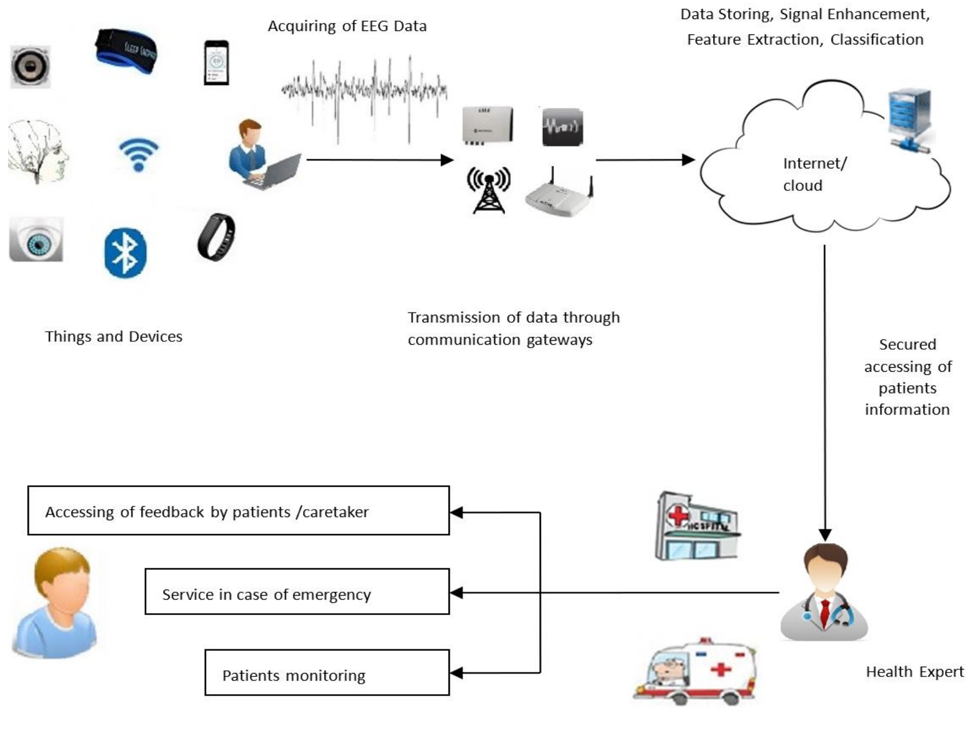


Figure 1. Proposed model of cloud based health IoT system for epileptic patient monitoring

4. METHODOLOGY AND WORKDONE

Cognitive IoT-cloud integration for smart healthcare, authors has been presented a system for epileptic patient monitoring and seizure detection [23] that represents how EEG signals were acquired and transmitted to the cloud for analysis. A cloud supported cyber physical localization framework for patient monitoring proposed here [24]. In this paper, watermarking of EEG signal has been performed, which is based on DWT-SVD method [25, 26].

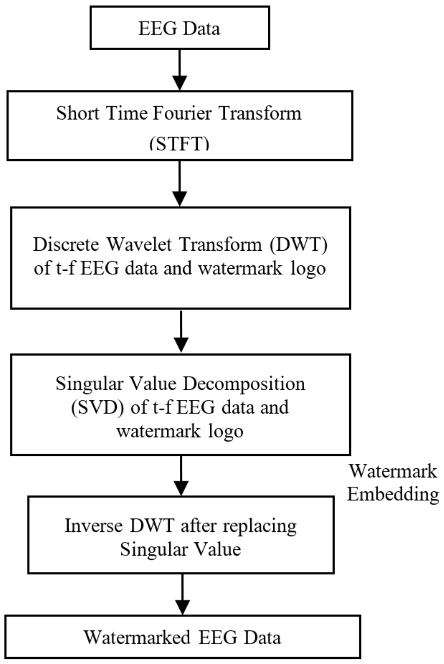


Figure 2. Steps for the achieving watermarking of EEG data

To perform watermarking, acquired EEG data must be pre-processed, to remove any unwanted component / noise from the signal. For this purpose, suitable filter and shaper (for smoothing the signal) can be used. In this paper, used dataset [27] is already pre-processed, hence didn't use any noise removal technique. To transform this time domain EEG data need to be transform in time-frequency domain, for that STFT has been used here. Now, watermarking can be performed on time-frequency domain data in order to secure the signal during transmission presented in Figure 2. In watermarking scheme, some particular information may embed with original signal without making any loss of information. Watermarking of EEG signal allow us to transmit information to the cloud through communication gateways in safer way. This paper uses an efficient approach of watermarking of EEG signal for securing the data of epileptical patients.

4.1 STFT of EEG data

In this paper, STFT has been used to perform time - frequency analysis of EEG data [28, 29]. STFT transforms one dimensional (time domain) EEG data to two dimension (time - frequency). In this work, hamming window of size odd (N/4) is used.

STFT of message (EEG) signal x (t) using short duration hamming window h (t) is given by the Eq. (1):

$$STFT(t,f) = x(t,f) = \int_{-\infty}^{\infty} x(\tau)h(\tau - t)e^{-if\tau}\,d\tau \qquad (1)$$

In Figure 3 represents STFT of EEG data. This shows (a) class Z EEG data, (b) STFT of class Z EEG data, (c) class S EEG and (d) represents STFT of Class S data, where horizontal and vertical axis represents number of samples in time and frequency respectively.

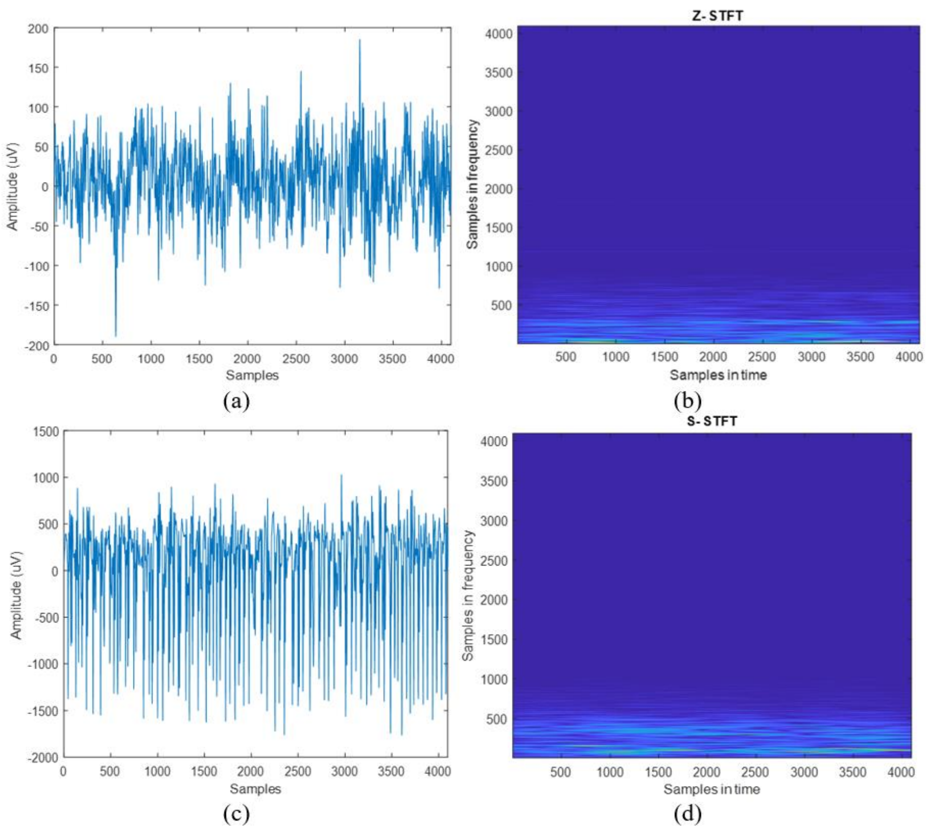


Figure 3. (a) Z class EEG data, (b) STFT of class Z, (c) S class EEG data, (d) STFT of class S

4.2 DWT-SVD based watermarking of EEG data

To perform watermarking of EEG data, collected from patients need to transform in time-frequency domain. Now, this obtained two dimensional EEG data requires securing for transmission. In this paper, DWT-SVD (discrete wavelet transform-singular value decomposition) based watermarking has been used to secure EEG data [25, 30, 31]. Wavelet transforms is one of the versatile mathematical transform having numerous applications indifferent areas. Wavelet transform has become an important tool in image processing and watermarking due to its good energy compaction properties. The basic idea of discrete wavelet transform (DWT) is to separate frequency detail and is based on small waves, called wavelets, of varying frequency and limited duration. Each level of decomposition of (DWT) separates an image into four sub-bands namely a lower resolution approximation component (LL) and three other corresponding to horizontal (HL), vertical (LH) and diagonal (HH) detail components. The LL sub-band is the result of low pass filtering in both the directions row and column and contains rough description of the image. DWT is a method that performs decomposition of signal into different levels of time and frequency. Here, two level of DWT using Haar filter has been used, considering that time-frequency domain message and watermark logo. DWT decomposes time domain message into various sub-bands namely LL2, LH2, HH2 and HL2 corresponding to decomposition of level two.

The SVD is based on a theorem of linear algebra which says that a rectangular matrix I_k can be partitioned into three matrices; an orthogonal matrix U_k, a diagonal matrix S_k and the transpose of an orthogonal matrix V_k. It can be seen as a method for transforming correlated variables into a set of uncorrelated ones that expose the various relationships among the original data in a better manner. SVD finds its significance in image processing as a digital image can be viewed as a matrix of non-negative scalar entries. SVD is used to factorize the matrix into three different matrices:

$$I_k = U_k\, S_k\, V_k^T \tag{2}$$

where, k represents each sub-band.

Now, SVD has been applied on watermark logo on the basis of respective sub-band and find the singular value S_{wk}.

$$W_k = U_{wk}\, S_{wk}\, V_{wk}^T \tag{3}$$

Now, it is needed to embed S_{wk} into S_k, here we are using Eq. (4) [26]:

$$S_{new} = \alpha * S_k + S_{wk} \tag{4}$$

where, α represents intensity of watermarking

$$I_k{}' = U_k\, S_{new}\, V_k^T \tag{5}$$

Now, Inverse DWT (IDWT) has to be applied on $I_k{}'$ to get watermarked EEG data in time-frequency domain.

5. EEG DATASET USED FOR WATERMARKING

In this paper, publically available dataset [27], provided by University of Bonn has been used for performing watermark in EEG data to enhance security of cloud based Health-IoT system. This available data is already preprocessed; hence without use of any noise removal technique dataset has been used as it is. It consists EEG data of healthy patient as well as epileptic patient. This dataset was collected during eye open and eye closed situation of healthy patient (Z and O respectively) and from epileptic patient, during seizure period (S) & seizure free period (N and F, during hippocampal formation and epileptogenic zone respectively) presented in Table 1. These collected EEG data is of duration of 23.6 seconds (4097 samples) and sampling frequency of 173.61 Hz.

Table 1. Representation of different classes of dataset

Subjects to collect EEG data	Class	Type	Way of data acquired
Healthy Person	Z	Normal	EEG signal acquired with eye opened
	O		EEG signal acquired with eye closed
Epileptic Patients	N	Seizure free	EEG signal from the hippocampal formation
	F		EEG signal from epileptogenic Zone
	S	Seizure	EEG signal acquired during seizure period

6. RESULTS

In this work, data from class Z and S has been chosen among five different classes of EEG data, to perform water marking. With the use of 100 segments of each Z and S class data, STFT has been used to perform time-frequency domain transformation of time domain in EEG data. Before transmission of EEG data to the cloud through communication gateways, there is a need of security. To secure EEG data DWT-SVD based watermarking has been performed on time-frequency domain of particular channel EEG data. Figure 4, representing watermarked Z and S class EEG data, which is obtained using standard Lena image as watermark logo.

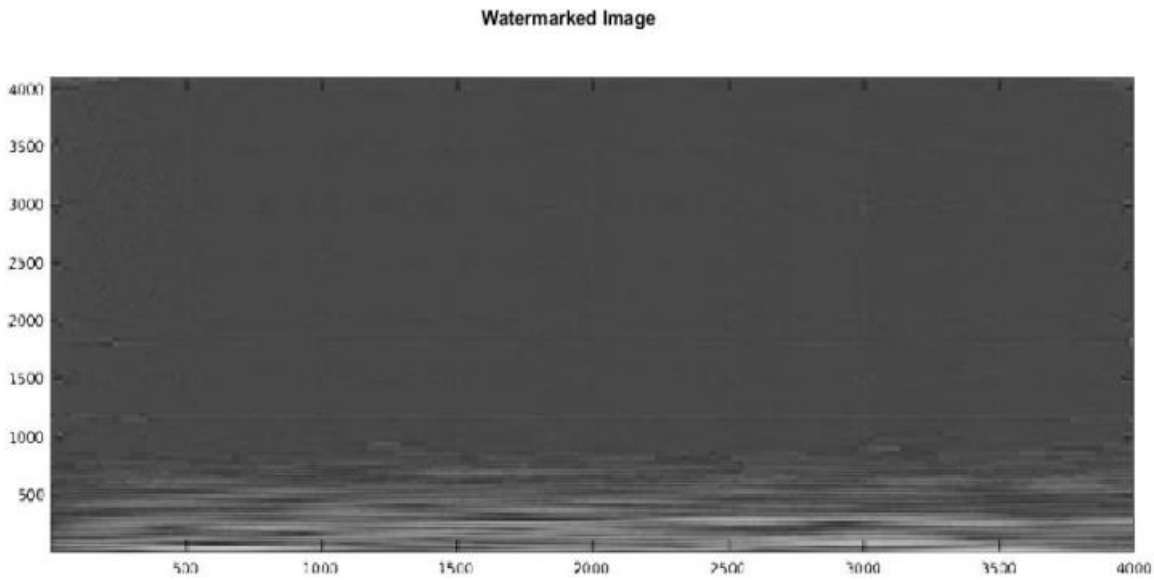
In this paper, due to watermarking, by how much amount EEG signal gets distorted is observed by imperceptibility [12]. This also gives the performance of EEG watermarking. To evaluate imperceptibility, we have used signal to noise ratio (SNR) presented by Eq. (6) given below:

$$SNR_{dB} = 10 \log_{10} \frac{P_s}{P_s - P_s{}'} \tag{6}$$

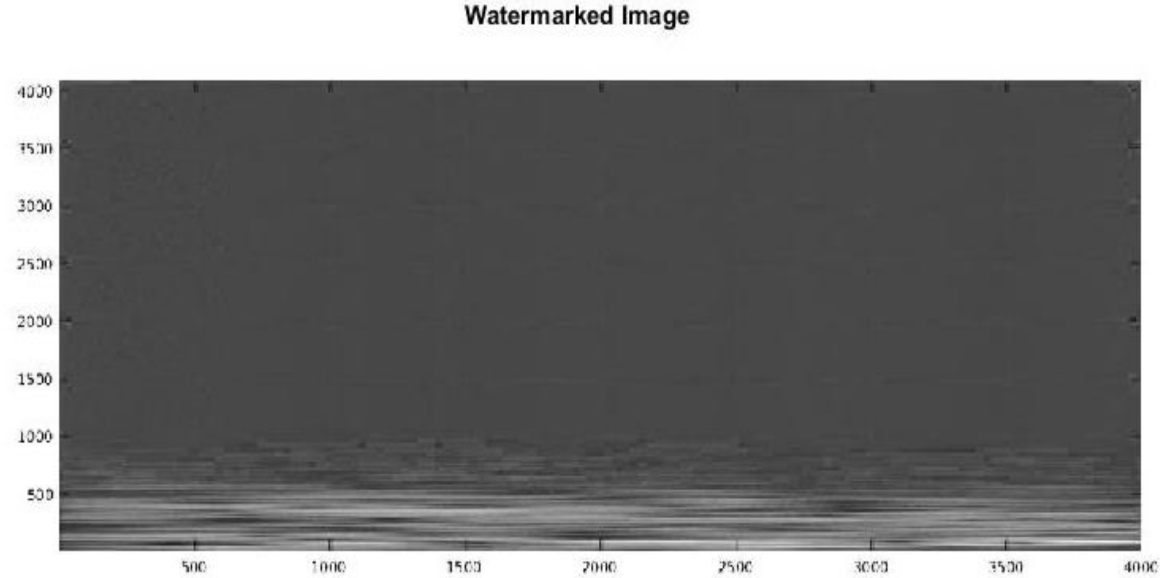
Here, PSNR (Peak Signal to Noise Ratio) value has also been evaluated. It is given by the ratio of maximum value of amplitude of EEG data to the mean squared deviation between EEG and watermarked EEG data [27], presented by Eq. (7).

$$PSNR_{dB} = 20 \log_{10} \left(\frac{\max(x_c)}{\sqrt{\frac{1}{N} \sum_1^N (x_c - x_w)^2}} \right) \tag{7}$$

Software MATLAB 17(a) is used to simulate the proposed DWT-SVD algorithm followed by STFT for the transmission of secured image combined with watermark logo and DWT. This paper has achieved a good watermarking performance.



(a)



(b)

Figure 4. Watermarked EEG data of: (a) Z class, (b) S class

Table 2. SNR and PSNR for respective class of EEG data

Values of α	EEG data	SNR	PSNR
0.25	Z class	31.3229	35.2501
	S class	31.2847	35.1836
0.75	Z class	23.3025	27.2297
	S class	23.2206	27.1195

Here, presented Table 2 shows the watermarking performance in terms of SNR and PSNR. On the basis of DWT-SVD watermarking algorithm, for class Z EEG data, achieved SNR and PSNR values are 31.32 and 35.25, whereas for class S EEG data these have the values 31.28 and 35.18 corresponds to value of α taken 0.25.

7. CONCLUSION AND FUTURE WORK

Cloud Based Health-IoT system for monitoring of epileptic patients is growing rapidly. Way of accessing of patient information by experts and accessing information / feedback given by experts to user is improving day by day. With this system, it becomes possible to monitor patient and provide suggestions in real time. Even though, there is an issue of data security, with the use of watermarking methods of EEG data, secure transmission also became possible, which provides safe and superior quality of service to patients.

In this paper, DWT-SVD based watermarking has been successfully applied on time -frequency domain EEG data and good watermarking performance achieved in terms of SNR and PSNR. Future work consist feature extraction and classification followed by watermark extraction from EEG data in the cloud itself, to detect or predict epileptical seizures on patient.

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NOMENCLATURE

N	number of data points (sample)
x(t)	message signal
h(t)	hamming window
x(t, f)	STFT of message signal

Greek symbol

α	intensity of watermarking

Subscripts

I_k	cover image (t-f message)
W_k	watermark logo
[LL2, LH2, HH2, HL2]	level 2 cofficients of cover image
S_k	singular value of cover image
U_k	orthogonal matrix
V_k'	Transpose of orthogonal matrix
S_{wk}	singular value of watermark logo
S_{new}	singular value of watermarked signal
P_s	Power of EEG data
P_s'	power of watermarked EEG data
x_c and x_w	amplitude of EEG and watermarked EEG data