Compressive Sensing Based Secure Storage and Transmission of Ultrasound Images

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Abstract

We propose a new way of storing and securing medical images over public networks. The real time ultrasound image information is simultaneously compress using sparse representation i.e. Structurally Random Matrices and encrypt via Arnold Transform. Considering the property of sparse nature, the original ultrasound image is compressed with structurally random matrices, which reduces the data volume. Further, compressed coefficients made more complex form using Arnold transformation for encryption. At the receiver end, the original image content can be reconstructed using recovery algorithm. Simulations and extensive security analyses shows that encrypting between fewer information of the image data is sufficient to provide high secured information and low data volume without degrading the quality of ultrasound Image.

Keywords: Fast compressive sensing, Ultrasound, Arnold Transform, Medical image Security.

1. Introduction

The increasing transmission and accessibility of digital medical information i.e. electronic health records (EHR) over public network makes hackers to illegally access patient's medical reports to easily duplicate or revise data [1]. Hence it is necessary to secure storage and transmission of information over public network. Several medical imaging communities issued guidelines and mandates for protection of patient information's since medical image security is severe threats in public and private networks [2].

In this paper, we present a fast Compressive sensing (CS) based US image encryption technique combined via Arnold transform (AT) in order to enhance the security and complexity of the system [see Fig. 1]. Our system can recover data by using only 25% of the measurements from the real time US image and encrypt it using AT. The proposed scheme is applied to in vivo US liver image, Simulations and numerical results shows the system to be more secure and complex.

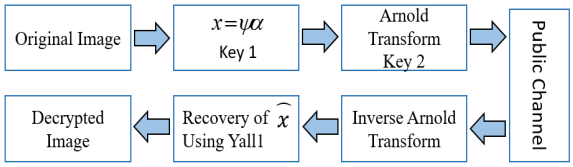

Fig. 1.The flow diagram of proposed scheme for US image encryption and decryption.

2. Principle of the methods

2.1. Arnold Transform

AT, also known as cat map transformation rearranges the pixel matrix points of digital image, after N times of shifting the digital image, pixel value is limited and restored to original image content [3].

2.2. Fast compressive sensing approach using structurally random matrices (SRM)

The CS algorithm used for simultaneous sampling and compression of signals. Many natural signals are sparse or compressible in transform domain, such as wavelet or discrete cosine transform (DCT) basis [4]. It consists of two elements i.e. sensing matrix and sparsifying operator.

$$x = \psi\alpha \qquad (1)$$

In our scheme we implemented a fast CS based method using structurally random matrices (SRM) that can be sparse in any domain [5]. For the reconstruction, we use yall-1 algorithm [6].

$$\hat{\alpha} = \arg\min \|\alpha\|_1 \qquad (2)$$

3. Experimental Results

We verify our proposed technique by applying in vivo ultrasound image obtained using US diagnostic system with size 580×462 and verified by introducing peak signal-to-noise ratio (PSNR) and histogram between original image and recovered image. The PSNR defined in following equation:

$$PSNR(R,O) = 10\log \frac{255^2}{\left(\frac{1}{MN}\right)\sum_{i=1}^{N}\sum_{j=1}^{M}[R(i,j)-O(i,j)]^2} \qquad (3)$$

Where *R(i,j)* is the reconstructed image and *O(i,j)* is the original image at pixel *(i,j)*.

Figure 2 shows the experimental results and found that our algorithm encrypts and reduce the size of image thus improved the efficiency of information transmission under precise reconstructing of original image and also the information is secured well.

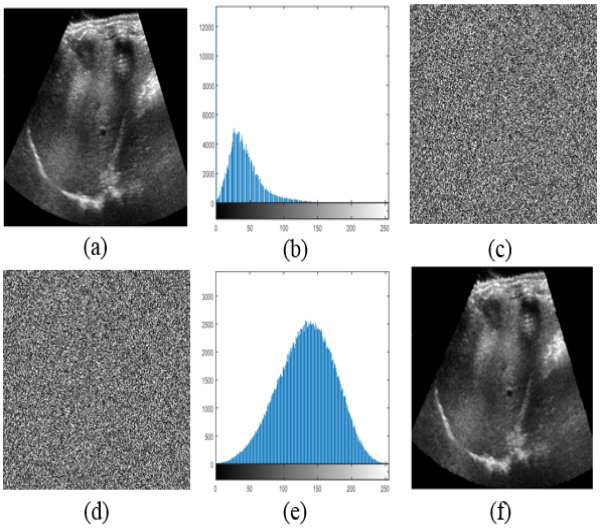

Fig. 2.Experimental results: (a) Original in vivo liver US image. (b) Histogram of the original image. (c) Scrambling image after SRM (d) Scrambling image using AT. (e) Histogram of the final scrambled image. (f) Decrypted output image with PSNR 23.456.

4. Security analysis with wrong key

In order to analyze the security of proposed scheme we intercept information illegally using random keys and found that decryption process execute successfully only if all keys are available. Figure 3 shows that decoding process is very sensitive to the right keys only and clearly visible that wrong parameters of CS and AT prove that high confidentiality of encoding process.

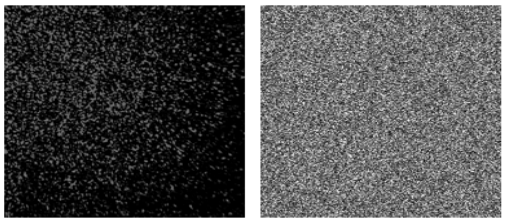

Fig. 3.Analysis of CS and AT with Wrong parameter (a) Original image with wrong SRM parameter, PSNR=2.852 dB and (b) with wrong inverse AT parameter, PSNR=1.382 dB.

5. Conclusion

In this paper, an ultrasound image has been encrypted and compressed using CS and AT approach. CS techniques is employed using modified random matrix generation and the AT is used to protect the image by shuffling the pixel of US image. Simulations and security analysis have demonstrated that even by using 25% of the measurements, a good quality image can be recovered. Our proposed method showed enhanced security, reliability, less computational time.

6. Acknowledgment

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