ULTRASOUND DATA COMPRESSION IN A TELE-ULTRASOUND SYSTEM

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Abstract
Healthcare improvement is a critical social issue nowadays. The diagnostic benefits of tele-ultrasound may not be available in locations with lack of high-bandwidth transmission channels because transmitting the large volume of the ultrasound data through the band limited signal channel is impossible. In these cases data compression is necessary because the purpose of data compression is to represent data with less bits in order to save storage costs and transmission time. Because of the importance of speckle structure in the ultrasound image, the Standard compression algorithms like conventional JPEG aren’t suitable for ultrasound images.

Key Words
Compression, Wavelet, Scan line, RLC, Huffman coding

1. Introduction
Modern medical ultrasound imaging systems generate quarter megabyte (or greater) sized images at frame rates exceeding 30 images per second. Efficient data compression is therefore necessary for ultrasound data storage and transmission. Existing data compression algorithms such as the conventional JPEG, however, cannot work as efficient as they work on photographic and broadcast television images because of the high frequency nature of the ultrasound images due to the intrinsic speckle patterns [1], [2]. The results of data compression algorithm for ultrasound data are presented in this paper.

The ultrasound beam is first directed along one line of sight into the body. Then the echoes of the ultrasound burst are received back and registered for this line, which is known as an “RF signal” or a “Scan line”. The compression algorithm is applied to the stream of the one-dimensional ultrasound scan lines data instead of compression of the ultrasound video images. Data volume largely decreases; therefore the processing time for compression is shortened [3], [4], and [5].

Each scan line was searched to find the peaks that show the points which rise to the largest output in a local neighborhood. To find the peaks of each scan line two ways were applied. In the first way, each scan line points were compared with a proper threshold that was chosen at the beginning for each scan line. After detecting the peaks, the amplitude of these peaks and the position of them were stored individually in two arrays. The Run Length Coding (RLC) scheme is employed to the Amplitude array to reduce the repeated data [6]. RLC scheme isn’t applied to the Position array due to lack of the repeated data. Then Huffman coding was used for both arrays. The second way was comparing all the wavelet coefficients of the scan line points with a suitable threshold chosen after applying wavelet transform to the scan line signals. The above process was done on the peak of the wavelet coefficients instead of the peak of the signals. The resulted values must be sent to the destination. After recovering the peaks, the other scan line points in the first way and the other wavelet coefficients in the second way were replaced with zeros.

2. Diagnostic Ultrasound Imaging
Ultrasound refers to sound waves with high frequency (about 18 kHz to 10 GHz) and ultrasonic imaging is produced by the reflection and refraction of ultrasonic waves at the interface of two different media [7]. When the ultrasound transducer is put against the skin of a patient near the region of interest, it converts the electrical impulse into an ultrasound wave beam which penetrates into the body and reflects back from the surface of the organs inside. Simultaneously, the transducer also acts as a receiver, which translates the ultrasound into electrical signals and detects sound waves as they bounce off from the internal structures and contours of the organs. Different tissues have different reflection waves, causing a signature that can be measured and transformed into an image. These electrical signals are amplified, demodulated, and finally turned into live pictures in an ultrasound system.

The most prominent artifact in the ultrasound image is known as the “speckle”, which is produced by the scattered waves from many small structures or non-smooth surface of the object. When ultrasound waves scatter from the tiny structures or small bumps of a surface, they interfere with each other and generate random echo patterns which are unrelated to the actual
pattern of scatters within the organ. The speckles are sometimes diagnostically important, and therefore should be preserved in the images. These bright light spots, or “speckles”, are located randomly over the entire image and therefore increase the energy in the high frequency subbands after a subband decomposition. Generally, ultrasound imagery is an important modality in medical imaging techniques that is relatively simple, easy to use, portable, and cost-effective compared to other medical imaging techniques.

3. Methods

Two methods were applied in this article. Threshold determination is necessary for both methods because the base work of the two methods is extracting the peaks of scan line signal or wavelet coefficients. To calculate the threshold, the average of each scan line is taken as a mean value. Various thresholds are considered as a percentage of the mean value.

The methods mentioned in this paper are based on saving and transmitting the peaks, so these methods preserve the speckles. The peaks are referred to the bright spots called speckles. For example; in a gray scale image (0-255), pixels with value more than mean value (128) are brighter and values less than 128 are darker. The speckles are the brighter spots therefore they are greater in amplitude (the peaks) and are preserved.

3.1 Method 1

In this method the mean value of each scan line signal is subtracted from each sample and the results is divided by the maximum value. This produces the smaller signal elements which is helpful in more effective compression of the RF signals. Then a suitable threshold according to the mean of signal is chosen. The signal element selection is based on a comparison between each signal sample with the threshold. The samples of each scan line that is greater than the threshold are kept and the smaller ones are omitted. In other words the amplitude of maximum values in each signal after thresholding will be saved in an array called “amplitude array”. The position of each amplitude array element is saved in another array named “position array”.

Then the Run length coding (RLC) scheme is employed to amplitude array to reduce the data size by grouping the long sequences of similar sample values into one codeword.

Huffman encoding is used to create and assign code words to the above results. Huffman encoding is also used to encode the position array.

The compressed Peaks of the RF signal includes, the Huffman codes, Huffman code book, the mean value and the maximum value of each scan line. These values must be sent to the destination in order to be able to recover the peaks and their positions for each scan line.

3.2 Method 2

This method is similar to method 1, but there is a difference between the two methods. That is regards the process which is done on the wavelet coefficients of each scan line [8]. It means that instead of choosing a suitable threshold for each scan line and comparing the scan line elements with this threshold a suitable threshold due to the wavelet coefficients is chosen and the wavelet coefficients are compared with this threshold. The coefficients greater than the threshold, were saved in the amplitude array and their positions were saved in the position array. RLC and Huffman coding are applied as the first method.

4. Experiments and Results

The described methods are implemented in Matlab. Examples of a desired scan line signal are drawn in figures 1 and 2.

Examples of ultrasound images and their decompressed versions after compressing with a chosen suitable threshold are shown in figures 3, 4, 5 and 6. The algorithm is applied to both real and synthetic ultrasound RF signals. Compression ratio (CR) and peak signal noise ratio (PSNR) are calculated for each case. The CR and PSNR due to the Salomon’s book are defined as bellow:

\[
CR = \frac{\text{size of output stream}}{\text{size of input stream}}
\]

\[
PSNR = 20 \log \left( \frac{255}{\text{RMSE}} \right)
\]

where RMSE is the root mean square error.

Table 1 shows a comparison between the two methods applied to the real RF signals and simulated RF signals which construct test object and kidney images respectively. It is obvious that method 2 gives a better CR and method 1 gives a better PSNR.

5. Conclusion

The scan line signals are compressed instead of compressing the image. The applied algorithms efficiently compress and reproduce speckled imagery.
Experiments and the above results show better compression in terms of CR and PSNR. The algorithm is applied to the one dimensional scan line signals so data volume decreases in a lossless method. Moreover, the processing time for compression of one dimensional data is much shorter which will surely benefit the real time implementation of the Tele-ultrasound system.

Fig1. The original scan line signal and the signal containing the local peaks of the original signal (the 60th scan line of the real RF signals in method1)

Fig2. The original scan line signal and the signal containing the local peaks of the original signal (the 60th scan line of the simulated RF signals in method1)

Fig3. From left to right: The original image, the reconstructed image, and the difference between the original and the reconstructed image in method1. (Test object image constructed by real RF signals) (CR=8.08 %, or 12.4:1, PSNR=57.15 dB)

Fig4. From left to right: The original image, the reconstructed image, and the difference between the original and the reconstructed image in method1. (Kidney image constructed by simulated RF signals) (CR=12.17 % or 8.2:1, PSNR=67.31 dB)

Fig5. From left to right: The original image, the reconstructed image, and the difference between the original and the reconstructed image in method2. (Test object image constructed by real RF signals) (CR=6.15 % or 16.3:1, PSNR=43.92 dB)

Fig6. From left to right: The original image, the reconstructed image, and the difference between the original and the reconstructed image in method2. (Kidney image constructed by simulated RF signals) (CR=8.18 % or 12.2:1, PSNR=54.17 dB)
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References


