Compression of uterine MMG signals using the DCT and the Huffman Coding

Dr. T Ananda Babu¹, P Padmavathi², V Mukhesh Goud³, V Naveen Kumar⁴

¹Assistant Professor, Dept. of ECE, Gudlavalleru Engineering College, Gudlavalleru, India
²Graduate Scholar, Dept. of ECE, Gudlavalleru Engineering College, Gudlavalleru, India
³Graduate Scholar, Dept. of ECE, Gudlavalleru Engineering College, Gudlavalleru, India
Corresponding Author: padmavathipamarthi@gmail.com

Abstract—The chances of morbidity and mortality of premature babies increases every year around the world. Appropriate care of these babies at the right moment through telemedicine and ambulatory monitoring is vital. The size of the uterine physiological signals restrains the practical applications. A lossless compression method proposed in the study as a combination of discrete cosine transform (DCT) and Huffman coding. The DCT components below the 2 Hz frequency were computed. The quantized DCT coefficients were coded by a Huffman coder on the transmitter site. A zero set instead of the DCT coefficients above 2 Hz, added at the receiver site. Inverse DCT applied to get the reconstructed signal. Uterine Magnetomyography (MMG) signals downloaded from the Physionet database were used in this study. The results indicate that the proposed algorithm is best suitable for the lossless compression of MMG signals.

Keywords—Lossless compression, discrete cosine transform, huffman coding, uterine MMG signals, physionet.

I. INTRODUCTION

Prediction of premature labor is very important factor as it increases the chances of morbidity and mortality of mothers and babies. According to the World Health Organization (WHO) report [1] preterm births increases in all countries which is the most worrying thing. Providing essential care at the right moment reduces the complications such as preventing infections to babies and mothers, etc. The pre-term symptoms can be monitored efficiently with the combination of health services and information technology. The transfer of physiological signals over a communication channel is essential for telemedicine. In recent years, many researchers focussed on lossless compression as the long-term records of physiological signals put a massive load on the channel.

At present, there are two methods that are used to record the physiological activity of the uterine: (i) the electromyography (EMG), recorded by electrodes attached to the abdomen, and (ii) the magnetomyography (MMG), based on the recording of the magnetic fields that correspond to electrical fields. The transition of the myometrium from nonlabor state to labor state can be identified by EMG/MMG. Uterine EMG/MMG parameters can indicate the myometrial properties. These properties are helpful to differentiate physiological contractions of term labor and preterm labor. Uterine MMG is a non-invasive technique and it measures the action potentials magnetic fields. The first uterine MMG activity recordings of uterine activity with a 151-channel sensor array were reported by Eswaran et al. [2].

The previous studies on uterine EMG/MMG were limited to the analysis of the signals for predicting labor and for the prevention of premature births. The compression algorithms focussed only on the surface EMG signals. EMG signals were compressed using embedded zero tree wavelet by Norris and colleagues [3]. Wavelet transform with a dynamic bit allocation scheme employed for compression in [4]. Multiscale multidimensional parser (MMP) algorithm proposed by Filho et al. [5] is suited for the compression of both EMG and EEG (Electroencephalogram) signals. The image compression techniques applied on surface EMG signals in [6, 7]. Trabucu et al. [8] employed discrete wavelet transform (DWT) with four different spectral functions for bit allocation. Vector quantization with SPIHT coding and arithmetic coding applied for EMG signal compression [9]. The coding techniques were employed to compare the transform techniques, discrete cosine transform (DCT) and DWT. The DCT technique used to compress EEG signals considering different number of coefficients [10, 11]. A hybrid algorithm that combines both DCT and Huffman coding for the compression of multichannel EEG signals gave best results according to [12, 13].

However, previous studies could not present the compression techniques application on the uterine physiological signals. Only research on this field is attempted by Cho et al. [14] to compress the uterine EMG signals dynamically. This attempt made the real-time transmission easier and lossless to monitor pre-term delivery in a medical information system. The present work focused on adopting the algorithm employed in [13] to compress the uterine MMG signals. It considers the 1/f characteristic of the DCT frequency spectrum along with Huffman coding. A single channel with high signal to noise ratio out of multichannel MMG signals (147 to 148 channels) considered for the study.

II. MATERIALS AND METHODS

A. Data acquisition and preprocessing

The MMG records used in this research are downloaded from Physionet database included with the MMG database (mmgdb) [15, 16]. The database comprises uterine magnetomyography (MMG) signals recorded by using the 151...
The MMG signals are recorded from 25 subjects who are in the trimester of pregnancy. The signals were recorded approximately around 20 min duration. The gestational age (GA) of the subjects is in the range of 37-40 weeks and 15 subjects, delivering less than 3 days after the SARA recording. The database contains channel names and clinical information:

- Body Mass Index
- Cervical dilation (dilation cm) / (effacement %) / (station)
- Days to delivery after SARA recording
- Gestation Age (weeks+days)
- Race.

The raw signals were digitized with a sampling rate of 250 Hz. The original data was sampled at 32 Hz (down sampling). The maternal & fetal cardiac signals were attenuated by using a bandpass filter (0.1-1 Hz). The notch filter (0.25-0.35 Hz) is used to remove the maternal breathing (0.33 Hz). Segments with the maternal movement were excluded from these signal to obtain the final MMG signals. Each recording lasts around 20 min and includes 147 to 148 channels. The channel with high signal to noise ratio is employed in this work. Figure shows the MMG signal for a single sensor of subject 202.

The DCT can express any function as an infinite series of cosine functions that oscillate at different frequencies. The DCT is formally defined using the equations (1) and (2).

\[ X(k) = \sum_{n} \omega(k) X(n) \cos \left( \frac{\pi(n-0.5)(k-1)}{N} \right) \]  

(1)

where \( X(k) \) and \( N \) are DCT and length of the original signal \( x(n) \) respectively.

and \( \omega(k) = \begin{cases} \left( \frac{1}{n} \right)^{0.5} & \text{for } k = 1 \\ \left( \frac{2}{n} \right)^{0.5} & \text{elsewhere} \end{cases} \)

The DCT frequency spectrum of the signal with a frequency step about 0.00049 Hz represented in figure 2. It represents the DCT transform of the signal presented in figure 1. The frequency step for the DCT is \( f_s = F_s/2L = 32/(2\times32640) = 0.00049 \). The \( F_s \) and \( L \) are sampling frequency and the length of MMG signal, respectively. From the figure we can observe that the DCT frequency spectrum has a 1/f characteristic. So the frequency components above 2 Hz are negligible and almost equal to zero. For lossless compression these high frequency components can be discarded.

C. Compression using the DCT and the Huffman coding

Huffman coding is the widely used method for coding the text, signal and image. It is an entropy based method that uses the probability to determine the number of bits for coding the symbols. Since the DCT coefficients of MMG signal have a Gaussian distribution, it is better to use the Huffman coding for lossless compression. We quantized the MMG signals uniformly in 20 levels by \( Y = f \left( \frac{\lfloor (N \times X_{\text{max}})/X_{\text{max}} \rfloor}{X_{\text{max}}-X_{\text{min}}} \right) \). Here \( N \) is the number of quantization levels while \( X \) represents the DCT coefficients respectively. The function \( f \) rounds the elements to the nearest integers. A suitable codebook based on the Huffman’s algorithm compresses these DCT coefficients efficiently. The Huffman’s codebook that is suitable to compress the DCT coefficients was checked and presented in Table 1.
Table 1: Huffman codes (codebook) corresponding to various quantization levels

<table>
<thead>
<tr>
<th>Row</th>
<th>Code</th>
<th>Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0</td>
<td>Maximum</td>
</tr>
<tr>
<td>2</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>110</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>1110</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>11110</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>111110</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>1111110</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>11111110</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>111111110</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>…….</td>
<td>Minimum</td>
</tr>
</tbody>
</table>

The compression algorithm is the combination of DCT and Huffman coding exploited in this study is represented as block diagram (Figure 3).

III. RESULTS AND DISCUSSION

At the transmitter site, the DCT of the original MMG signal was computed. The DCT coefficients above 2 Hz were discarded. Then the quantized DCT coefficients using a Huffman coder were transmitted. At the receiver site, the DCT coefficients were decoded using a Huffman decoder. Then a zero set added to the decoded signal instead of the high frequency coefficients (above 2 Hz). Inverse DCT applied later on these coefficients to get the reconstructed signal. Figure 4 shows an example of original and the reconstructed MMG signals.

The performance metrics used in the study are compression ratio, percentage root-mean-square difference (PRD), correlation rate, signal to noise ratio (SNR) and mean squared error (MSE). The parameters for the proposed algorithm are recorded in table 2.

Figure 5 presents the effect of quantization on the compression ratio and the correlation rate of a reconstructed MMG signal (subject 202). As the number of quantization levels increases, the compression ratio decreases with an increase in correlation rates. This figure shows that 20 quantization levels can be a good selection for the compression of this MMG signal. The compression ratio and the correlation rate between the original and reconstructed signal were 3.61 and 95.02%, respectively. Note that the values represented in Table 2 are the maximum/minimum values that can be achieved by the proposed method irrespective of number of quantization levels.

Table 2: Performance metrics of the proposed algorithm

<table>
<thead>
<tr>
<th>Compression Ratio</th>
<th>Correlation rate</th>
<th>PRD</th>
<th>SNR</th>
<th>MSE</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.9188</td>
<td>99.0831</td>
<td>13.6485</td>
<td>39.833</td>
<td>0.0103</td>
</tr>
</tbody>
</table>

The results of discarding DCT coefficients above a certain frequency for different signals indicate that the DCT components below 2 Hz for MMG signals have more information to reconstruct. So discarding the DCT coefficients can significantly compress the information of MMG signals. Two types of errors, i.e. the error caused by discarding the DCT coefficients and the quantization error, were neglected in this study. To compensate these errors effects on performance metrics, we considered the tradeoff between performance metrics instead of precise values. The results obtained in this study was not compared to other signals, as the signals other than uterine MMG have different and unique characteristics. The compression ratio obtained here is similar to that one in
as the signals considered in both cases were the uterine physiology signals.

IV. CONCLUSION

A high compression ratio and correlation rates are necessary for physiological signals that are used in the remote health care services. Since the uterine EMG/MMG signals indicates the maternal health, data loss at any stage leads to the severe clinical errors. The proposed algorithm (combination of the DCT with Huffman coding) is best suitable for the lossless compression of multichannel MMG signals. Though the present work carried out on term records, it can be used for any signal that have a 1/f characteristic in the frequency spectrum. The proposed algorithm with appropriate hardware can enable the medical professionals to make the right decisions at “Golden Time” during post-natal period.

References


