ROBUST APPROACH FOR MINIMIZING SIZE OF TRANSMITTED SOUND SIGNAL USING WALSH–HADAMARD TRANSFORM

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Abstract --In this paper, a new approach of compressing sound signal based on the Walsh–Hadamard transform has been proposed. The compression issue is performed by considering limited interval in the transformed plane of the sound signal as a transmission data based on the knowledge that most of the energy of the signal is focused on high coefficients area of the Walsh–Hadamard transform. Consequently, on the receive side the sound signal is reconstructed using the inverse Walsh–Hadamard transform. The missing part of the transformed spectrum will be compensated with a calculated value for all coefficients in the missing part. The reconstructed sound signal is evaluated with the original sound signal using the standard metrics of signal accuracy. The simulation results from the proposed approach view significant percent of accuracy for the reconstructed signal.

Keywords- Walsh–Hadamard transform, Sound Signal, compressing approach.

I. INTRODUCTION

The orthogonal transform and its fast algorithm play an important role in digital signal/image processing, cryptography and other fields. Commonly used orthogonal transforms include discrete cosine transform (DCT), Fourier transform, wavelet transform, Laplace transform, Walsh transform, etc. [1-5]. As a global transform, DCT cannot be effective on the recognition of local features. Fourier transform and the subsequent short-time Fourier transform may analyse the signal characteristics from the viewpoint of frequency domain, but the time frequency localization capability is limited. Because of the localization recognition ability and the multi-resolution features, wavelet analysis has a good performance in the signal processing. For many years, the researches on the theory and application of wavelet analysis have been continuously performed, and have still been unfolding currently.

II. THE WALSH–HADAMARD TRANSFORM

In general, the Hadamard transform (HT) is an orthogonal and lossless transform, with the potential of energy compaction. Elements of Hadamard basic vectors take only 1 and values, resulting in straightforward and simple realizations suitable for hardware efficient digital signal processing. The HT matrix, \( H_n \), is a \( 2^n \times 2^n \) matrix, and can be recursively defined as

\[
HH_n = \frac{1}{\sqrt{2^n}} \begin{pmatrix} H_{n-1} & H_{n-1} \\ H_{n-1} & H_{n-1} \end{pmatrix}
\]

in which, \( H_0 = 1 \), and \( n=1,2, \ldots \) [6]. Components of the HT matrix can also be obtained by properly sampling a set of orthogonal basis functions called the Walsh functions, taking only the values 1 and -1. In this case, the transform is called the Walsh–Hadamard transform (WHT). The WHT\(_n\) ( \( n\)-th-order WHT) of a input vector, \( X \), is written as

\[
Y = H_n \cdot X
\]

where \( Y \) is the output \( 2^n \times 1 \) vector. It should be noted that the consecutive \( 2^n \) -sample windows defined on the input signal are non-overlapping [6].

Being a symmetric and orthogonal transform, the WHT matrix has the following properties:
and

$$H_n = H_n^T$$ \hspace{1cm} (3a)

$$H_n^{-1} = H_n^T$$ \hspace{1cm} (3b)

respectively. As a result

$$H_n^{-1} = H_n$$ \hspace{1cm} (3c)

meaning that the same matrix, $H_n$, can be used for the inverse Walsh–Hadamard transform, $\text{WHT}^{-1}$. This facilitates the transfer of the original signal from the WHT space back to the time domain.

As a result of applying the WHT, energy of the signal is shaped in such a way that it is concentrated in a certain region in the WHT space [7]. As it will be described later, energy compaction property of the WHT can facilitate compression in the neural data while the main information of the signal is preserved. The extent of energy compaction, however, depends on how the input data vectors are correlated [7].

Perhaps the most attractive aspect of the WHT is that it is implemented using merely adders, subtractors and registers, with no need for multipliers. This is simply because the transform matrix, $H_n$, contains only 1 and -1 values. As a result, hardware implementation of the WHT will be simple and rather power and area efficient.

Finally, highest percent of input signal is focused in the high WHT coefficients as shown in Figure (1).

![Figure (1): Distribution of signal energy using WHT.](image)

III. PROPOSED METHODOLOGY

As mentioned in the previous section, limited interval of the transformed plane using WHT can be considered to represent maximum percent of signal energy. Thus, the new approach of compressing the sound signal takes this knowledge as base to implement compression issue on the sound signal. The general block diagram of the proposed approach is described in figure ()
IV. SIMULATION RESULTS

In this section, the proposed approach of compressing sound signal is applied on the sound signal with 14,848 samples at 12,500 Hz. Five different active intervals are considered in this implantation (2, 4, 8, 16, and 32) in order to evaluate quality of the reconstructed sound signal in each considered interval. As followed in any similar work, the evaluation of the reconstructed sound signal is determined by some standard quantitative metrics like mean square error (MSE), percent root mean square difference (PRD)) which are mostly used to evaluate the performance of any approaches that is applied on digital signal to determine the quality of the reconstructed signal with respect to the original transmitted signal. The second and third metrics (MSE, PRD) defined in (4) and (5), respectively determines the percent of similarity between original and reconstructed signal.

\[
MSE = \frac{1}{N} \sum_{i=1}^{N} (X_o(i) - X_F(i))^2 \tag{4}
\]

\[
PRD[db] = \frac{\sqrt{\sum_{i=1}^{N} (X_o(i) - X_F(i))^2}}{\sum_{i=1}^{N} X_o^2(i)} \times 100 \tag{5}
\]

4-1 Analytic Evaluation

The simulation results of the standard metrics (MSE, PRD) of the previous implementation using the five trials of active periods are illustrated in Table (1).
Table (1): Validation Results of standard metrics (MSE and PRD) for Five Active periods

| Active Period | Percent of division (1/k) | MSE     | PRD (%) |
|---------------|--------------------------|---------|---------|
| 1             | 1/32                     | 6.7E-3  | 85.53%  |
| 2             | 1/16                     | 3.4E-3  | 60.41%  |
| 3             | 1/8                      | 1.2E-3  | 35.49%  |
| 4             | 1/4                      | 3.62E-4 | 19.82%  |
| 5             | 1/2                      | 1.29E-4 | 11.83%  |

4-2 Graphical Evaluation

Another evaluation is performed to evaluate the texture of the reconstructed sound with the respect to the original one. As the similarity between the reconstructed signal and original one gives the robustness of the proposed approach to reconstruct maximum percent power of the input sound signal. The simulation results of five trials considered in the previous evaluation and the original signal are shown in Figure (3, a...f), respectively.

(a) ![Graphical Evaluation](image1)
(b) ![Graphical Evaluation](image2)
(c) ![Graphical Evaluation](image3)
(d) ![Graphical Evaluation](image4)
Figure (3): Original Sound Signal and the reconstructed Sound Signal from the proposed Approach using the five trials (1/2, 1/4, 1/8, 1/16, and 1/32) active periods.

V. CONCLUSION

In this paper, a new approach of compressing sound signal for reducing transmitted information via a transmission media has been proposed. The proposed approach follows very simple techniques for reducing the transmitted information by considering limited period from the transformed plane of Walsh–Hadamard transform as the active data and ignoring reminder samples in the transformed plane. Continuously, in the receiving side, the received data is integrated with limited vector of fixed level. Five active periods are selected to evaluate the performance of the proposed approach using same sound signal. The simulation results prove the capability of the proposed approach to reconstruct sound signal with high precision of accuracy also, save the same texture behaviour of the processed signal.

In this study, a new approach of ECG signal noise reduction has been proposed. The new approach follows simple scaling operation that applied on the WT detail resolution of noisy signal along two levels using symlet wavelet filter with eight coefficients. The proposed approach successes to reduce largest percent of noise from all parts of ECG signal. Also, the new noise reduction approach is characterized by simple implementation, reliability for different SNR levels, and reconstructed signal with high accuracy. Simulation results of the standard metrics related to noise reduction show that the new approach performs more accurate outcomes in comparison with the existing methods of ECG signal noise reduction.

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