Comparative Study of Compression Techniques Applied in Different Biomedical Signals

A. A. Saraiva[2,3][a], F. M. J. Castro[1][b], Nator Junior C. Costa[1][c], Jose Vigno M. Sousa[1][d], N. M. Fonseca Ferreira[4,5][e], Antonio Valente[3,6][f], Salviano Soares[7][g]

[1] *UESPI-University of State Piaui, Piripiri, Brazil*

[3] *School of Science and Technology, University of Trás-os-Montes and Alto Douro, Vila Real, Portugal*

[4] *Department of Electrical Engineering, Institute of Engineering of Coimbra, Coimbra, Portugal*

[5] *Knowledge Engineering and Decision-Support Research Center (GECAD) of the Institute of Engineering, Polytechnic Institute of Porto, Portugal*

[6] *NESC-TEC Technology and Science, Campus da FEUP, Rua Dr. Roberto Frias, 378,4200 - 465 Porto, Portugal*

[7] *IEETA – UA and University of Tras-os-Montes and Alto Douro, Vila Real, Portugal*

Keywords: Compression and Signal and Electrooculography and Algorithms.

Abstract: This paper aims to compare the compression of electro-oculographic signals, based on the (EOG) from MIT / BIH database, and the electromyographic signals, based on the (EMG) from MIT / BIH database, for that purpose, two compression techniques that can be used in electro-oculograms and electromyograms was approached, the two techniques mentioned above, were, the discrete cosine transform and Fast Walsh Hadamard Transform. For statistic the methods used was, the Mean squared error, mean absolute error, signal-to-noise ratio and peak signal-to-noise ratio as well, and for results, the techniques and they performance on each tested signal.

SCIENCE AND TECHNOLOGY PUBLICATIONS

1 INTRODUCTION

With the constant development of computing, the amount of information needed for humans inevitably grows.

The volume of information carriers and the capacity of communication channels increase, but the amount of information grows faster.

In this way the compression and decompression procedure is a solution for a more rational use of the storage and data transfer devices.

One of the medical applications is related to the bio-medical signs, among them the ocular ones from the electrooculography (EOG), and the muscular ones from the electromyography (EMG).

[a] https://orcid.org/0000-0002-3960-697X
[b] https://orcid.org/0000-0002-7751-9455
[c] https://orcid.org/0000-0001-5636-424X
[d] https://orcid.org/0000-0002-5164-360X
[e] https://orcid.org/0000-0002-2204-6339
[f] https://orcid.org/0000-0002-5798-1298
[g] https://orcid.org/0000-0001-5862-5706

Most modern EMG systems for algorithms for data compression, capabilities for storing and transmitting large data equipment via GSM / GPRS, Internet and other communication channels for complete telemedicine systems.

The problems about expansion of the signal storage resources are being solved at the present moment, mainly due to the use of the technique of ”compression” with losses. At the same time, the ability to analyze data in ”full report” mode, which is accessible to analog methods and in some cases important information about rhythm disturbances and changes not recognized by the microprocessor are lost.

Data compression is the process of detecting and eliminating redundancies of a data set. In terms of signal compression techniques, direct or transformed methods were found in most of the literature. They are characterized by not reaching the highest level of compression, have no control over the quality of the recovered signal.

In this paper, the efficiency of two compression and decompression methods will be studied from

Saraiva, A., Castro, F., Costa, N., Sousa, J., Ferreira, N., Valente, A. and Soares, S.
Comparative Study of Compression Techniques Applied in Different Biomedical Signals.
DOI: 10.5220/0007350401320138
In *Proceedings of the 12th International Joint Conference on Biomedical Engineering Systems and Technologies (BIOSTEC 2019)*, pages 132-138
ISBN: 978-989-758-353-7
Copyright © 2019 by SCITEPRESS – Science and Technology Publications, Lda. All rights reserved

EOG, and EMG signs: FWHT and DCT. The data are analyzed in terms of signal quality and compression level and they come from the MIT/BIH database.

The document is divided into 7 sections, in which section 2 and 3 is characterized by explanation of methods used, followed by section 4 in which it shows the metric comparison of the method. It follows the formulation of the central algorithm applied in section 5 and the statistical method to verify reliability. The results after application of the proposal are presented in section 6 and the conclusion in section 7.

2 ELECTROOCULOGRAPHY

Electrooculography (EOG) is a technique for measuring the corneo-retinal standing potential that exists between the front and the back of the human eye. The resulting signal is called the electrooculogram. Primary applications are in ophthalmological diagnosis and in recording eye movements. Unlike the electroretinogram, the EOG does not measure response to individual visual stimuli.

To measure eye movement, pairs of electrodes are typically placed either above and below the eye or to the left and right of the eye. If the eye moves from center position toward one of the two electrodes, this electrode "sees" the positive side of the retina and the opposite electrode "sees" the negative side of the retina. Consequently, a potential difference occurs between the electrodes. Assuming that the resting potential is constant, the recorded potential is a measure of the eye's position (Brown et al., 2006).

Electro-oculography is used to record eye movements during electronystagmographic testing. It is based on the corneoretinal potential (difference in electrical charge between the cornea and the retina), with the long axis of the eye acting as a dipole. Movements of the eye relative to the surface electrodes placed around the eye produce an electrical signal that corresponds to eye position. Recordings of eye movement are accurate to about 0.5 degree, but it is still less sensitive than visual inspection, which can perceive movements of about 0.1 degree. Therefore, visual inspection with Frenzel lenses is sometimes still necessary to document nystagmus of low amplitude. Another limitation of electro-oculography is that torsional eye movements cannot be monitored. Again, visual inspection with Frenzel lenses is sometimes necessary to document torsional nystagmus(Saraiva et al., 2018b).

Fortunately, new techniques have been developed to provide greater accuracy and breadth for oculomotor testing. The most clinically useful technique that has been developed is the infrared video electronystagmographic system. Here, the patient wears goggles that illuminate the eyes with infrared light (invisible to the patient), allowing a small video camera to pick up and project an image of the eyes onto a monitor. This can also assess eye movement in horizontal, vertical, and torsional directions and is more accurate than electro-oculography(das Chagas Fontenele Marques Junior et al., 2018) (Schapira, 2006).

3 ELECTROMYOGRAPHY

The EMG is the process by which an examiner puts a needle into a particular muscle and study the electrical activity of that muscle, this electrical activities come from the muscle itself no shocks are used to stimulate the muscle, by that is possible to find a muscle who present a particular problem or disease(Weiss et al., 2015).

The excitability of a muscle fibers through neural control represents a major factor in muscle physiology, for that the EMG is a technique concerned with the development recording and analysis of myoeletric signals, the signals taken by this process are formed by physiological variations in the state of muscle fiber membranes, by that some diseases and problems can be detected if the variation don't follow the normal patterns under minor exceptions(Konrad, 2005), there's another way to measure the EMG,is the neurological EMG, by this way electrical shocks are used to stimuli the muscle, but on this work, the kinesiologic EMG will be approached, on this type only the natural response of the muscle are taken as object of study then for that are used to take the signal.

4 DCT - DISCRETE COSINE TRANSFORM

The DCT is very related to the Discrete Fourier Transform (DFT), it can often reconstruct a precise sequence of only a few DCT coefficients, this property is very useful for applications that require data reduction, precisely the purpose of this work, to explore the reduction of data use in electrocardiogram, (Nguyen et al., 2017). The DCT has four standard variants, for an x-signal of size N and with the kronecker δ, the transformations are defined by the equations1, 2, 3 and 4 respectively.

$$y(k)=\sqrt{\frac{2}{N}}\Sigma_{N-1}^{N}x(n)\frac{1}{\sqrt{1+\ delta_{n1}+\delta_{nN}}}\frac{1}{\sqrt{1+\delta_{k1}\delta_{kN}}}cos\left(\frac{\pi}{N-1}(n-1)(k-1)\right) \quad (1)$$

$$y(k)=\sqrt{\frac{2}{N}}\Sigma_{n-1}^{N}x(n)\frac{1}{\sqrt{1=\delta_{k1}}}cos\left(\frac{\pi}{2N}(2n-1)(k-1)\right) \quad (2)$$

$$y(k)=\sqrt{\frac{2}{N}}\sum_{n-1}^{N} x(n)\frac{1}{\sqrt{1+\delta_{n1}}}cos\left(\frac{\pi}{2N}(n-1)(2k-1)\right) \quad (3)$$

$$y(k)=\sqrt{\frac{2}{N}}\sum_{n=1}^{N} x(n)cos\left(\frac{\pi}{4N}(2n-1)(2k-1)\right) \quad (4)$$

The series are indexed with n = 1 and k = 1 instead of the usual n = 0 and k = 0.

On the equations, x is meaning the input array, y are the DCT itself and n is equal to the length of the transform, a positive integer scalar, with x and y being vectors (they can be matrices), (Nguyen et al., 2017).

In his work, Swarnkar using the standlet transform achieved better results compared to DCT and Wavelet transform, being able to illustrate well its results using data like SNR, also used in this work, CR and Price Related Differential (PRD), (A.Swarnkar et al., 2017).

A DCT expresses a series of finitely many data points in terms of a sum of cosine functions. Oscillate at different frequencies. DCT has the applications of solving partial differential equations, Chebyshev approximation, audio compression, (Raj and Ray, 2017).

5 FWHT- FAST WALSH HADAMARD TRANSFORM

The WHT is a non-sinusoidal, orthogonal transformation technique that decomposes the signal into a series of base functions, these base functions are called Walsh functions, which are rectangular and square waves with values of -1 and 1. They are also known as Hadamard, Walsh, or Walsh Fourier transform.

They are very useful in reducing the requirements of storage, bandwidth and spectrum analysis. Like Fast Fourier Transform (FFT) the WHT has a faster version to Fast Walsh Hadamard Transform (FWHT), which compared to FFT requires less storage space and is faster to calculate, since it uses only real additions and subtractions, whereas the FFT uses complex values.

Both the FWHT and the Inverse Fast Hadamard Transform (IFWHT) are symmetric to each other and use identical calculation processes (Saka et al., 2016).

For a signal $x(t)$ of size N the FWHT and IFWHT are defined as follows:

$$y=\frac{1}{N}\sum_{i=0}^{n-1} xWAL(n,i) \quad (5)$$

$$x=\sum_{i=0}^{n-1} yWAL(n,i) \quad (6)$$

Where i=0,1...,N-1 and WAL(n,i) are the Walsh functions. Similar to the Cooley-Tukey algorithm for the FFT, the N elements are decomposed into two sets of N/2 elements, which are then combined using a butterfly structure to form the FWHT, (Saka et al., 2016).

6 STATISTICS

For the achievement of the quality of compressed and reconstructed signal classification, compared with the original signal was used the Mean Squared Error (MSE), MAE, SNR, PSNR.

6.1 MSE

The MSE is a signal fidelity meter. The purpose of a fidelity meter is to compare two signals and provide a quantitative score that describes the degree of similarity or fidelity and the level of error or distortion between them, assuming that one of the signals is primitive and error-free while the other is distorted and contaminated by errors (Saraiva et al., 2018c). The MSE can be calculated as the equation 7, shows.

$$MSE=\frac{1}{mn}\sum_{x=0}^{m-1}\sum_{y=0}^{n-1} I-K^2 \quad (7)$$

Taking I, as a n predictions vector and K, as a vector of observed values of the variable being predicted.

6.2 MAE

The MAE is a ”scaled” measure, in this, it expresses a precise prediction model of errors in units of the variable of interest, as well as the MSE, the smaller the value, the greater the fidelity signal.

$$MAE=\frac{1}{n}\sum_{i=1}^{n}|e_i| \quad (8)$$

Reconstructed to the original signal, the MAE can be calculated assuming that there are n sample model errors e calculated as (e_i,i=1,2,...,n), (Willmott and Matsuura, 2008).

6.3 SNR

SNR is the rate between signal and noise, in engineering and science the SNR is the measurement that compares the level of the desired signal with the background noise level.

Mathematically the SNR is the intensity quotient of a signal measured in a Region of Interest (ROI) and

SCITEPRESS SCIENCE AND TECHNOLOGY PUBLICATIONS

the standard deviation of the signal intensity in an area outside the imaged object's anatomy.

$$SNR = Log\frac{\sum_{n=0}^{N} V_R^2(n)}{\sum_{n=0}^{N} S_R^2(n)} \quad (9)$$

The SNR can be calculated assuming $V_R(n)$ as the reconstructed signal, $V(n)$ as the original Signal and the $S_R(n)$ as the deformation of the reconstructed Signal, (Princy et al., 2015).

6.4 PSNR

The PSNR is a parameter used to quantify the signal quality, it is also used as a benchmark, of the level of similarity between the reconstructed signal and the original signal.

The higher the PSNR value, the better the signal quality. And can be calculated as the Equation 10, shows.

$$PSNR = 10\log\left(\frac{MAX^2}{MSE}\right) = 20\log\frac{MAX}{MSE^{\frac{1}{2}}} \quad (10)$$

7 METHODOLOGY

In the Fig.1, was exemplified the step by step of this work in a simple block diagram, the example shows the process of comparison between the two compression techniques, FWHT and DCT.

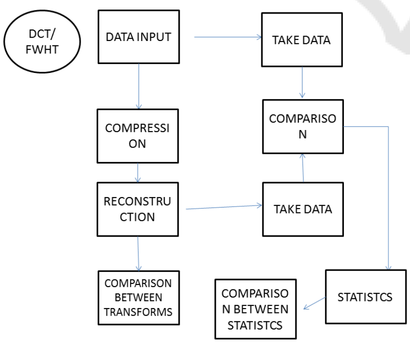


Figure 1: Methodology Block diagram.

First, the signal is taken from a source in this case the MIT-Database Chosen from the database of EOG and EMG signal, sometimes the signal taken has noise so the filtering was necessary, then, the signal who was input is loaded to the software , then the data is taken from it the data will be used to a comparison later, before that, the compression technique is applied to the signal, if the FWHT is applied, the signal is repeated 8 times, and then random noise is added before the compression, on the DCT case it won't be necessary to repeat the signal.

After compressed the signal, we get the data from the input signal, and for that the inverse transform of the respective compression technique is added, getting with that, a reconstructed signal, the reconstructed signals may vary depending of the compression technique, in this case, the FWHT has as the reconstructed signal 8x bigger than DCT reconstructed signal because of the repetition used early.

Before that, the data of the reconstructed signal was compared to the size of the original signal of the respective technique, then after the comparison between the original and the reconstructed signal in mind that the FWHT reconstructed signal must be compared with the 8x repeated Original signal because of it size, and the DCT reconstructed signal must be compared with the original signal as well because of it size keeping in mind that the signal behave on different ways according to the compression and reconstruction technique(Saraiva et al., 2018d).

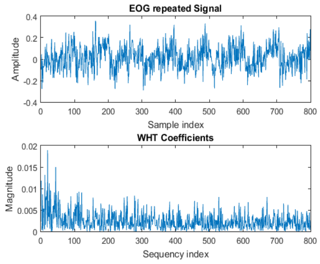
To do so, the statistic used are the MSE, MAE, SNR and PSNR with them, the signal quality and similarity can be tested, according to the results given by the mentioned statistic methods the MSE and MAE statistic methods, test the signal fidelity of the reconstructed signal compared to the original signal for both FWHT or DCT keeping in mind that each technique has its own size of original and reconstructed signal, on the FWHT the signal was 8 times repeated to get the coefficients WHT, also the PSNR and the SNR test the quality of the reconstructed signal compared to the original signal having as well the cautions to each Technique used on this work as mentioned above (Saraiva et al., 2018a) (Saraiva et al.,).

8 RESULTS

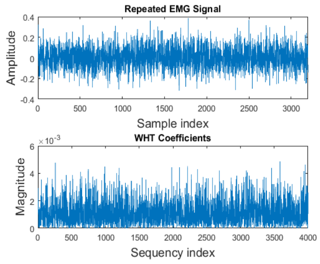
After the methodology used the signals were graphically represented to increase the understanding of this work the next images will show the comparison of the reconstructed signals and the original ones then show the statistic results to discuss the work before the conclusion.

In the Fig 2(a), are showed a 8x repeated EOG and the WHT coefficients of it, with that its possible to obtains the Walsh functions using the FWHT, each sample uses on the EOG example, was taken from the right eye readings the same is shown on the Fig 2(b), but with the EMG, also is showed its WHT coefficients.

In the Fig 3(c) and Fig 3(d), is showed graphically the original and the reconstructed by IDCT sig-

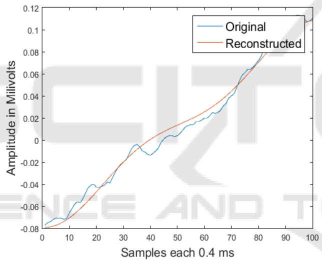


(a) Repeated EOG and WHT coefficients

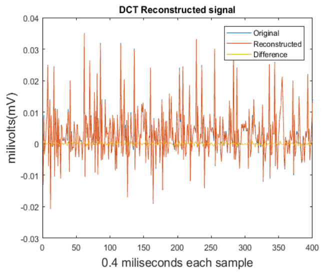


(b) Repeated EMG and WHT coefficients

Figure 2.

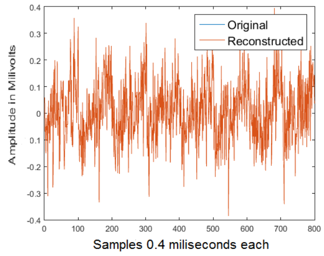


(c) IDCT reconstructed EOG signal

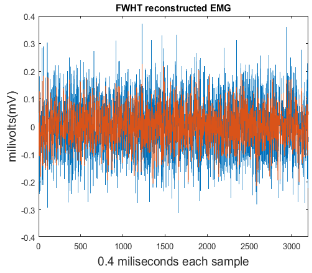


(d) IDCT reconstructed EMG signal

Figure 3.



(e) IFWHT reconstructed EOG signal



(f) IFWHT reconstructed EOG signal

Figure 4.

nals, showed in the graphic in different colors, exemplified on the legend each sample the original EOG, original EMG and the reconstructed are nearly similar, of course, taking the graphic as basis, that occurs because the DCT have a small loss rate, keeping in mind, the low difference seen in the graphic above.

In the Fig 4(e) and Fig 4(f), are showed the result obtained after the signals passes through the FWHT, being converted into WHT coefficients, or Walsh functions, with that its possible to use the IFWHT to obtain the reconstructed signals.

Table 1: Discrete cosine Transform.

Transform	Test	Value
DCT	PSNR	24.876553
DCT	SNR	19.1117
DCT	MAE	0.005583
DCT	MSE	0.000043

On the table 1, are exemplified the results of the statistic methods applied on the DCT EOG reconstructed signal.

Table 2: Fast Walsh Hadamard Transform.

Transform	Test	Value
FWHT	PSNR	13.90701
FWHT	SNR	-4.374118
FWHT	MAE	0.078406
FWHT	MSE	0.009601

On the table 2, are showed the results of the statistic methods applied on IFWHT EMG reconstructed signal.

On the table 1, are exemplified the results of the statistic methods applied on the DCT reconstructed EMG signal.

On the table 2, are showed the results of the statistic methods applied on IFWHT EMG reconstructed signal.

SCITEPRESS SCIENCE AND TECHNOLOGY PUBLICATIONS

Table 3: Discrete cosine Transform.

Transform	Test	Value
DCT	PSNR	39.214499
DCT	SNR	27.158767
DCT	MAE	0.000299
DCT	MSE	0.000000

Table 4: Fast Walsh Hadamard Transform.

Transform	Test	Value
FWHT	PSNR	-5.723057
FWHT	SNR	-17.778790
FWHT	MAE	0.052583
FWHT	MSE	0.004576

9 CONCLUSION

In a direct comparison between the above-mentioned transforms, the FWHT obtained advantage because the reconstructed signal approached the original signal and its compression was much more efficient.

DCT has proven itself to be effective with a very precise reconstruction of the compressed EOG in addition to the need for signal repetition. as seen in the images above, the graph of the DCT is relatively close to that of the original EOG taking as example the errors that were the lowest compared to the FWHT.

The DCT was proven itself most effective on a direct comparison in the EMG case for that the DCT is the best transform between the analyzed ones to EMG With greater advantage than on the EOG.

keeping in mind the results obtained, we see that the compression techniques discussed have their distinct particulars in certain aspects, therefore, we must always take into account that in some cases the results may not be identical.

for future work, it is interesting to classify a larger variety of transforms and their performances as the DWT (Discrete Wavelet Transform) into a wider range of medical signals, such as ECG (Electrocardiogram) and EEG (Electroencephalogram).

ACKNOWLEDGMENTS

This work is financed by National Funds through the FCT - Fundação para a Ciência e a Tecnologia (Portuguese Foundation for Science and Technology) as part of project UID/EEA/00760/2019.

REFERENCES

A.Swarnkar, Kumar, R., Kumar, A., and Khanna, P. (2017). Performance of different threshold function for ecg compression using slantlet transform. in signal processing and integrated networks (spin). volume 37, pages 375–379.

Brown, M., Marmor, M., Zrenner, E., Brigell, M., Bach, M., et al. (2006). Iscev standard for clinical electro-oculography (eog) 2006. *Documenta ophthalmologica*, 113(3):205–212.

das Chagas Fontenele Marques Junior, F., Saraiva, A. A., Sousa, J. V. M., Ferreira, N. F., and Valente, A. (2018). Manipulation of bioinspiration robot with gesture recognition through fractional calculus. In *IEEE LARS 2018 – 15th Latin American Robotics Symposium, SBR 2018 – 6th Brazilian Robotics Symposium, 2018*. IEEE.

Konrad, P. (2005). The abc of emg. *A practical introduction to kinesiological electromyography*, 1:30–35.

Nguyen, B., Nguyen, D., Ma, W., and Tran, D. (2017). Investigating the possibility of applying eeg lossy compression to eeg-based user authentication. In *Neural Networks (IJCNN), 2017 International Joint Conference on*, pages 79–85. IEEE.

Princy, R., Thamarai, P., and Karthik, B. (2015). Denoising eeg signal using wavelet transform. *International Journal of Advanced Research in Computer Engineering & Technology*, 3.

Raj, S. and Ray, K. C. (2017). Ecg signal analysis using dct-based dost and pso optimized svm. volume 66, pages 470–478.

Saka, K., Aydemir, Ö., and Öztürk, M. (2016). Classification of eeg signals recorded during right/left hand movement imagery using fast walsh hadamard transform based features. In *Telecommunications and Signal Processing (TSP), 2016 39th International Conference on*, pages 413–416. IEEE.

Saraiva, A. A., Castro, F. M. J., Sousa, J. V. M., Valente, A., and N M Fonseca, F. (2018a). Comparative study between the walsh hadamard transform and discrete cosine transform. In *7th International Conference on Advanced Technologies*.

Saraiva, A. A., Costa, N. J. C., Sousa, J. M., Araujo, T. P. D., Ferreira, N. M. F., and Valente, A. (2018b). Scalable task cleanup assignment for multi-agents. *Memorias de Congresos UTP*, 1(1):439–446.

Saraiva, A. A., Ferreira, N. M. F., Soares, S. F., Reis, M. J. C. S., and Valente, A. Filtering of cardiac signals with mathematical morphology for qrs detection. In *Proceedings of ICAT'18, 7th International Conference on Advanced Technologies, pp. 1008-1017, 28 April-1 May, Antalya, Turkey, ISBN 978-605-68537-1-5, 2018*. IEEE.

Saraiva, A. A., Ferreira, N. M. F., and Valente, A. (2018c). New bioinspired filter of dicom images. In *Proceedings of the 11th International Joint Conference on Biomedical Engineering Systems and Technologies - Volume 1: BIODEVICES,*, pages 258–265. INSTICC, SciTePress.

Saraiva, A. A., Nogueira, A. T., Ferreira, N. F., and Valente, A. (2018d). Application of virtual reality for the treatment of strabismus and amblyopia. In *2018 IEEE 6th International Conference on Serious Games and Applications for Health (SeGAH)*, pages 1–7. IEEE.

Schapira, A. H. (2006). *Neurology and clinical neuroscience*, volume 1. Elsevier Health Sciences.

Weiss, L. D., Weiss, J. M., and Silver, J. K. (2015). *Easy EMG E-Book: A Guide to Performing Nerve Conduction Studies and Electromyography*. Elsevier Health Sciences.

Willmott, C. J. and Matsuura, K. (2008). Advantages of the mean absolute error (mae) over the root mean square error (rmse) in assessing average model performance. In *Climate research*. JSTOR.

SCITEPRESS
SCIENCE AND TECHNOLOGY PUBLICATIONS