

Comparison between transforms a behavior qualitative analysis of various biomedical signals

Comparação entre transformadas uma análise qualitativa do comportamento de vários sinais biomédicos

Comparación entre transformadas un análisis cualitativo de comportamiento de diversas señales biomédicas

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Abstract

This paper aims to compare the behavior of different signals when applied to different compression techniques, to test and find the best compression techniques for each different signal, also proving that different signals behave differently in distinct types of compression, the results of this work were satisfactory to prove that different types of compression can be used on signals to achieve better results.

Keywords: Algorithms; Biomedical signals; ECG; EEG; EMG; EOG; Compression.

Resumo

Este trabalho tem como objetivo comparar o comportamento de diferentes sinais quando aplicados a diferentes técnicas de compressão, para testar e encontrar as melhores técnicas de compressão para cada diferente sinal, comprovando também que diferentes sinais se comportam de maneira distinta em diferentes tipos de compressão, os resultados deste trabalho foram satisfatórios. Para provar que diferentes tipos de compressão podem ser usados em sinais para obter melhores resultados.

Palavras-chave: Algoritmos; Sinais biomédicos; ECG; EEG; EMG; EOG; Compressão.

Resumen

Este trabajo tiene como objetivo comparar el comportamiento de diferentes señales cuando se aplica a diferentes técnicas de compresión, para probar y encontrar las mejores técnicas de compresión para cada señal diferente, demostrando también que diferentes señales se comportan de manera diferente en distintos tipos de compresión, los resultados de este trabajo fueron satisfactorios para demostrar que se pueden usar diferentes tipos de compresión en señales para lograr mejores resultados.

Palabras clave: Algoritmos; Señales biomédicas; ECG; EEG; EMG; EOG; Compresión.

1. Introduction

With the consistent improvement of figuring, the measure of data required for people unavoidably develops. The volume of data transporters and the limit of correspondence channels increment, however the measure of data becomes quicker. In this manner the pressure and decompression method are an answer for a more objective utilization of the capacity and information move gadgets.

The vast majority of the clinical applications is identified with the bio-clinical signs,

among them the visual ones from the electrooculography (EOG), the solid ones from the electromyography (EMG), the cerebral ones from the electroencephalography (EEG) the heart ones from the electrocardiography (ECG).

Innovative headway has caused it feasible for registering to get omnipresent. In the emergency clinic condition, it was conceivable to make versatile frameworks to complete the biophysics and organic checking. One of the most significant observing is identified with the electrical movement of the heart, electrocardiogram (ECG).

Electroencephalography (EEG) is a strategy for recording and inspecting electrical fields framed during cerebrum work. It is a moderately reasonable however significant strategy. Most present-day EMG frameworks for calculations for information pressure, abilities for putting away and sending enormous information gear by means of GSM/GPRS, Internet and other correspondence stations for complete telemedicine frameworks.

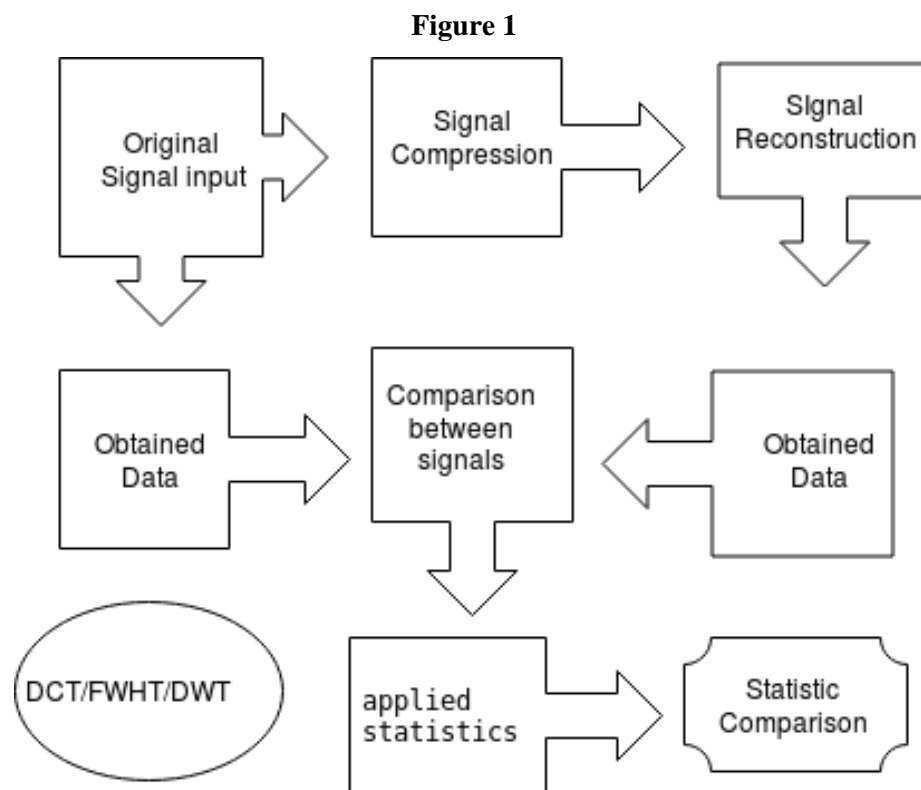
The issues about extension of the sign stockpiling assets are being understood at the current second, fundamentally because of the utilization of the procedure of "pressure" misfortunes. Simultaneously, the capacity to examine information in "full report" mode, which is open to simple techniques and sometimes significant data about cadence unsettling influences and changes not perceived by the chip are lost.

Information pressure is the way toward recognizing and killing redundancies of a dataset. Regarding signal pressure strategies, immediate or changed techniques were found in the greater part of the writing. They are described by not arriving at the most elevated level of pressure, have no influence over the nature of the recuperated signal (Alotaiby et al. 2015). The EEG and ECG signals originate from the MIT/BIH information base, can be found on the physiobank page (Saraiva et al. 2019), likewise the examination between pressure procedures and the conduct of signs as per each sort of method so as to look for and better approach to treat them is an approach to improve the utilization of biomedical innovation remembering that there a couple of number of works that analyze nature of a sign as indicated by the change applied on the sign.

In this paper, is demonstrated factually that distinctive biomedical signs, have diverse condition when applied on various pressure procedures and furthermore is indicated the correlation, that shows the better change to each flag between the signs and changes drew closer.

2. Methodology

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



Source: Authors.

To start with, the sign is taken from a source for this situation the MIT-Database browsed the information base of EEG signals, some of the time the sign taken has clamor, so the separating was vital, at that point, the sign who was input is stacked to the product , at that point the information is taken from it the information will be utilized to a correlation later, before that, the pressure method is applied to the sign, on the off chance that the FWHT is applied, the sign is rehashed multiple times, and afterward arbitrary commotion is included before the pressure, on the DCT and DWT case it won't be fundamental.

After compacted the sign, we get the information from the info signal, and for that the backwards change of the individual pressure strategy is included, getting with that, a remade signal, the recreated signs may shift depending of the pressure procedure, for this

situation, the FWHT has as the reproduced signal 8x greater than DCT and DWT recreated signal due to the reiteration utilized early.

2.1 Electroencephalography

The EEG is an electrophysiological monitoring method to record electrical activity of the brain. It is typically noninvasive, with the electrodes placed along the scalp, although invasive electrodes are sometimes used such as in electrocorticography. EEG measures voltage fluctuations resulting from ionic current within the neurons of the brain (Schomer and Da Silva 2012).

In clinical contexts, EEG refers to the recording of the brain's spontaneous electrical activity over a period of time, as recorded from multiple electrodes placed on the scalp.

Diagnostic applications generally focus either on event-related potentials or on the spectral content of EEG. The former investigates potential fluctuations time locked to an event like stimulus onset or button press. The latter analyses the type of neural oscillations, popularly called "brain waves", that can be observed in EEG signals in the frequency domain (Akansu et al. 2001).

2.2 ECG signal morphology

The heart has as a functional characteristic the presence of an expert excitatory system that develops an electrical activity action, ending up in a transformation of electrical energy in mechanical energy (heart beats) Schor (2004).

Prior to that, the information of the remade signal was contrasted with the size of the first sign of the particular procedure, at that point after the examination between the first and the recreated signal as a primary concern that the FWHT reproduced signal must be contrasted and the 8x rehashed Original sign as a result of its size, and the DCT recreated signal must be contrasted and the first sign also due to its size remembering that the sign act on various ways as per the pressure and reproduction strategy, in the DWT the sign won't pass by a reiteration (Saraiva et al. 2015).

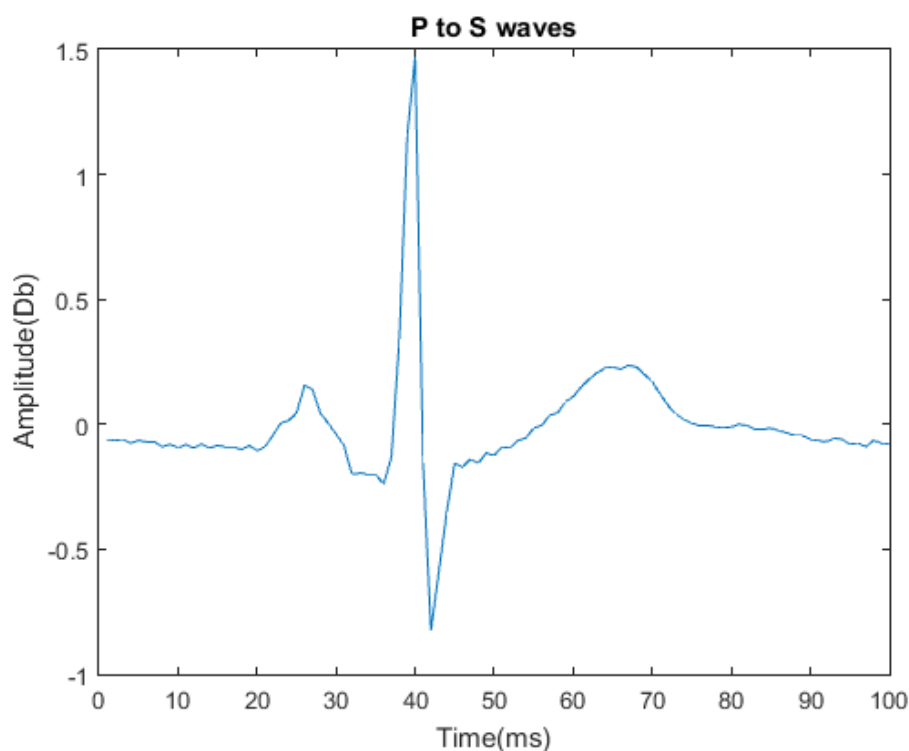
To do as such, the measurements utilized are the MSE, MAE, SNR and PSNR with them, the sign quality and likeness can be tried, as indicated by the outcomes given by the referenced measurement strategies the MSE and MAE measurement techniques, test the sign devotion of the remade signal contrasted with the first sign for both FWHT, DWT or DCT

remembering that every method has its own size of unique and recreated signal, on the FWHT the sign was multiple times reshaped to get the coefficients WHT, additionally the PSNR and the SNR test the nature of the reproduced signal contrasted with the first sign having also the alerts to every Technique utilized on this work as referenced above (Saraiva et al. 2018a) additionally the computational time on every calculation was lower than one second.

The generation of this signal is a responsibility of specialized muscles, being the sinus node the main responsible of inducing impulses through the heart. This signal is transmitted to adjacent tissues, principle that is how electrical signals captured in some points of the body can be seen as ECG waves, in a pack of waves compound by five basics waves denoted P, Q, R, S and T.

The generated electrical potential is a result of depolarization of the atria, denoted P wave, which has different characteristics in shape and amplitude. QRS consists of ventricular depolarization, and when they recover from a depolarization state is called T wave, known as repolarization wave, as shown in Figure 2.

Figure 2



Source: Authors.

Registry of a normal electrocardiogram Guyton and Hall (2006). Based on this wave

package, ECG is divided on three phases, PQ, QRS and ST, which analysis is an important and precise tool to assess and diagnose cardiac pathology.

Computational techniques for detecting these events can be impaired by many sources of artifacts, such as: muscle contraction, induced or radiated interference from the power grid and the patient's breathing. Other problems are related to the equipment: signal conditioning circuit, signal acquisition, filter characteristics and representation of the signal in digital form.

2.3 Electrooculography

Electrooculography (EOG) is a technique for measuring the corneoretinal 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).

Electrooculography 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 3 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 electro nystagmographic 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 (Chagas Fontenele Marques Junior et al. 2018) (Schapira 2006).

2.4 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, these 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 myoelectric 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 ET AL 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 kinesiological 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.

2.5 Discrete Cosine Transform

The DCT is a lossy technique, 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 Equation 1, Equation 2, Equation 3 and Equation 4 respectively.

Equation 1

$$y(k) = \sqrt{\frac{2}{N}} \sum_{n=0}^{N-1} x(n) \frac{1}{\sqrt{1 + \delta_{n1} + \delta_{nN}}} \frac{1}{\sqrt{1 + \delta_{k1} + \delta_{kN}}} \cos\left(\frac{\pi}{N-1}(n-1)(k-1)\right)$$

Equation 2

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

Equation 3

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

Equation 4

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

The EMG is the process by which an examiner puts a needle into a particular muscle and study the electrical activity of that muscle, these 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 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 is 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 stand let 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, Compression Ratio 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 Ray2017).

2.6 Fast Walsh Hadamard Transform

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 Ray2017).

The WHT is a lossy 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 in the equations 5 and 6.

Equation 5

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

Equation 6

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

Where $i = 0, 1, \dots, N - 1$ 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).

2.7 Discrete Wavelet Transform

In numerical analysis and functional analysis, a discrete wavelet transform (DWT) is any wavelet transform for which the wavelets are discretely sampled. As with other wavelet transforms, a key advantage it has over Fourier transforms is temporal resolution: it captures

both frequency and location information (location in time).

The first DWT was invented by Hungarian mathematician Alfred Haar. For an input represented by a list of $2n$ numbers, the Haar wavelet transform may be considered to pair up input values, storing the difference and passing the sum. This process is repeated recursively, pairing up the sums to prove the next scale, which leads to $2n-1$ differences and a final sum (Ranjeet et al. 2011).

Multi-resolution techniques for signal and image processing have been in use for decades. The need for transforms that lead to a representation in which both spatial and scale information are present, is widely recognized. In order to provide this, several related techniques were developed, including Gabor, Haar, Walsh-Hadamard and other expansions, sub band filtering scale space decompositions, etc. (Junior et al. 2018).

Around 1990, a mathematical framework emerged which provides a more formal, solid and unified approach to multi-resolution representations. The wavelet paradigm encompasses multi-resolution decompositions of signals into orthogonal bases of wavelet functions which have compact support. In a few years' laps of time, the wavelet paradigm has found many applications in signal and image processing (Akansu et al.2001).

The principle is to, first, compute a trivial wavelet transform (the lazy wavelet) and then improve its properties by alternating prediction and update steps as depicted in the figure. The lazy wavelet only splits the 1D signals into its even and odd indexed samples as shown on the equations 7 and 8.

Equation 7

$$s_{1,l}^{(0)} = s_{1,2l}$$

Equation 8

$$d_{1,l}^{(0)} = s_{1,2l+1}$$

The prediction step consists in applying a filter to even samples and subtracting the result from the odd ones, as exemplified on the equation 9.

Equation 9

$$d_{1,l}^{(1)} = d_{1,l}^{(0)} - \sum_k P_k S_{1,l-k}^{(0)}$$

The update step does the opposite, applying a filter to the odd samples and subtracting the result from the even samples, starting by that is possible to prepare the signal to be reconstructed as it shown on the equation 10.

Equation 10

$$d1_{1,l}^{(1)} = d1_{1,l}^{(0)} - \sum_k U_k D_{1,l-k}^{(0)}$$

Then, for the WHT After M pairs of prediction and update steps, the even samples will represent the approximation coefficients while the odd samples represent the high frequency coefficients (Cvetkovic et al. 2008).

The lifting scheme is perfectly reversible since the inverse transform is derived by reversing the operations and flipping the signs. Indeed, we alternate prediction and update steps (Cardenas-Barrera et al. 2004). Then, we apply the inverse lazy transform. The inverse transform can immediately be derived from the forward by running the scheme backwards and flipping the signs as is shown in the equation 11 and 12.

Equation 11

$$s1_{1,l}^{(0)} = s1_{1,l}^{(1)} + \sum_k U_k^{(1)} D_{1,l-k}^{(1)}$$

Equation 12

$$d1_{1,l}^{(0)} = d1_{1,l}^{(1)} - \sum_k p_k^{(1)} S_{1,l-k}^{(1)}$$

Keeping in mind that signal can be easily reconstructed with the sign flipping in the prediction step, so, according to the equations above, it is worth pointing out that the lifting scheme provides a lossless integer-to-integer transform, since it allows us to retrieve exactly the integer input 1D signal.

2.8 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.

2.8.1 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 13, shows.

Equation 13

$$MSE = \frac{1}{mn} \sum_{x=0}^{m-1} \sum_{y=0}^{n-1} I - k^2$$

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

2.8.2 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 as is shown in equation 14.

Equation 14

$$MAE = \frac{1}{n} \sum_{i=0}^n |e_i|$$

Reconstructed to the original signal, the MAE can be calculated assuming that there are n sample model errors calculated as $(\epsilon_i, i = 1, 2, \dots, n)$ (Willmott ET AL 2008).

2.8.3 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 the standard deviation of the signal intensity in an area outside the imaged object's anatomy shown in equation 15.

Equation 15

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

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.

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

2.8.4 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 16, shows.

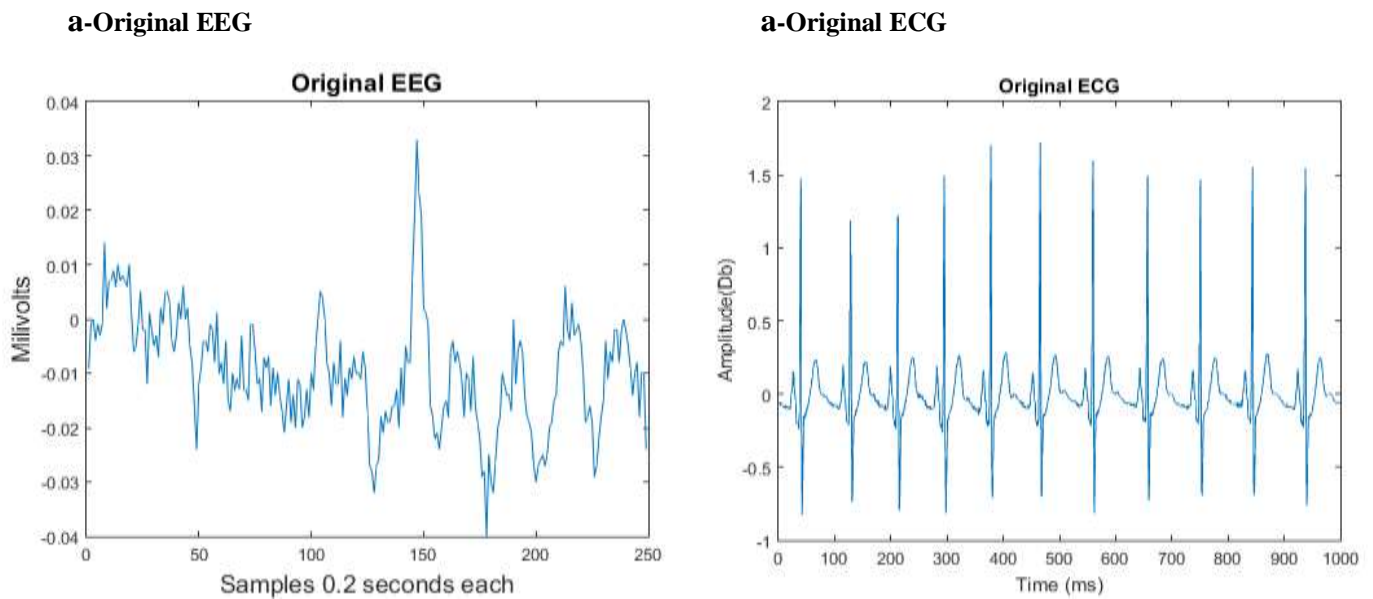
Equation 16

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

3. Results and Discussion

In the Figure 3(a), are showed an Original EEG C4 to A1 waves mean, that's the signal example used on this work the picture is shown in the time domain to better understanding and in the 3.b is the 10s reading of an ECG.

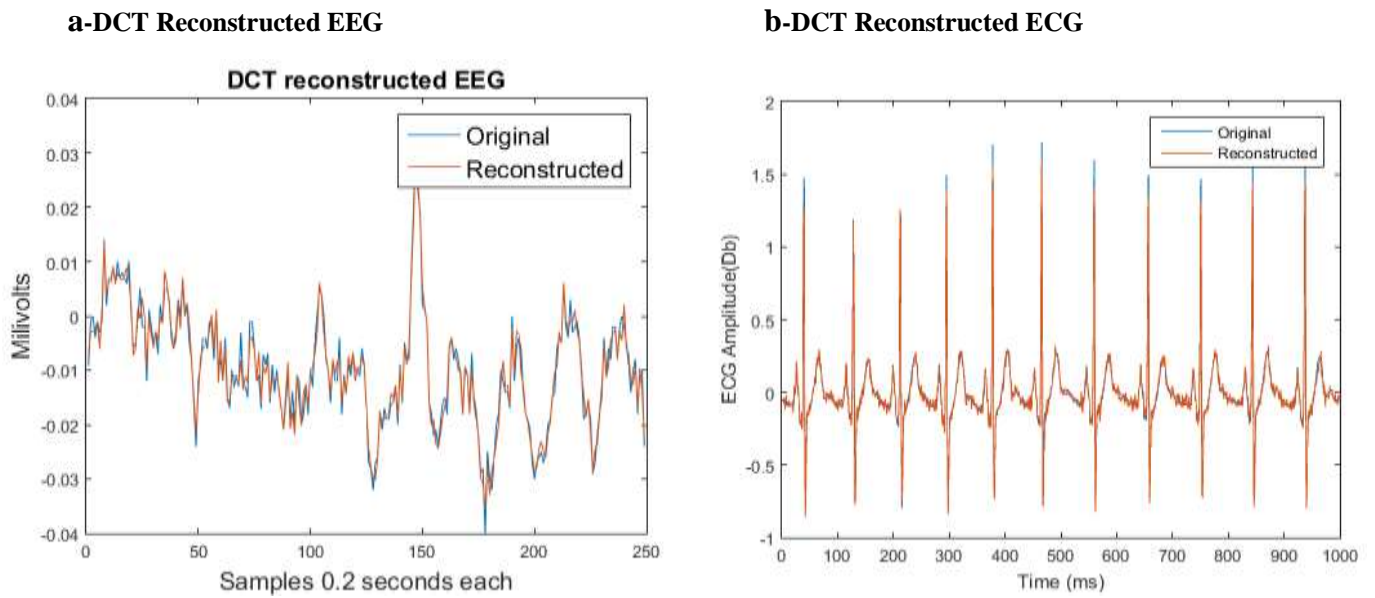
Figure 3



Source: Authors.

In the Figure 4, is showed graphically the original and the reconstructed signals who was tested with the DCT, keeping in mind that the reconstructed signals were not identical because of the noise addiction

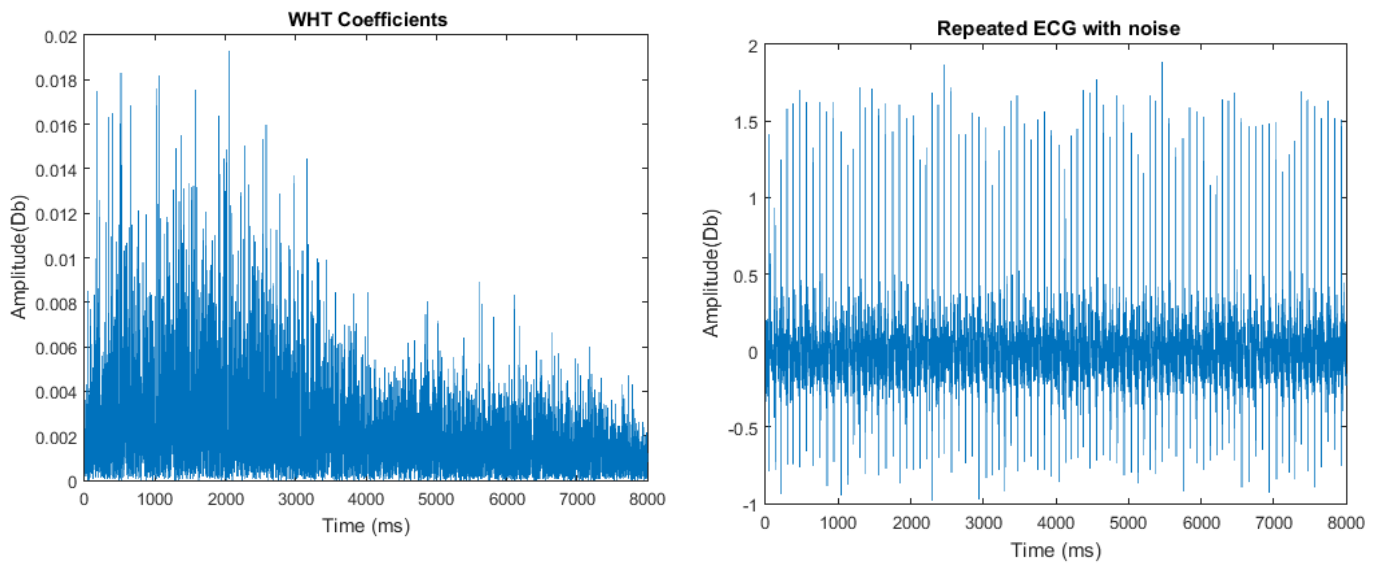
Figure 4



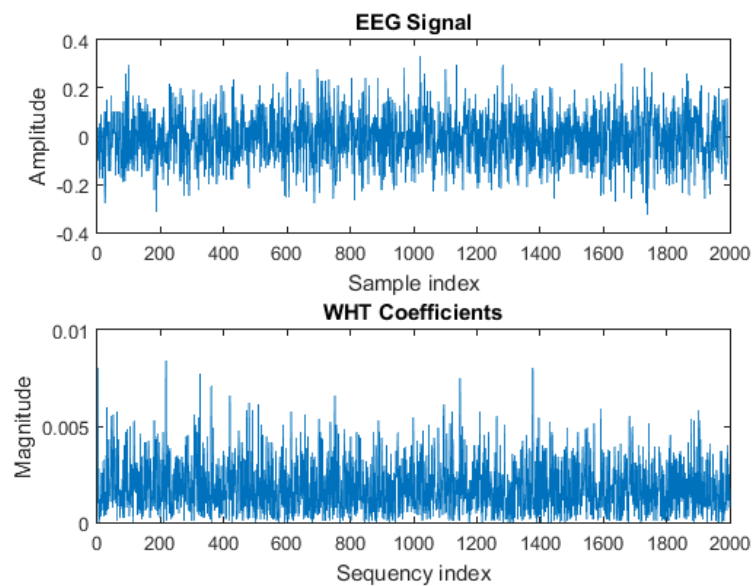
Source: Authors.

In the Figure 5, are showed the result obtained after the signal passes through the FWHT, being converted into WHT coefficients, or Walsh functions, with that it's possible to use the IFWHT to obtain a reconstructed signal.

Figure 5



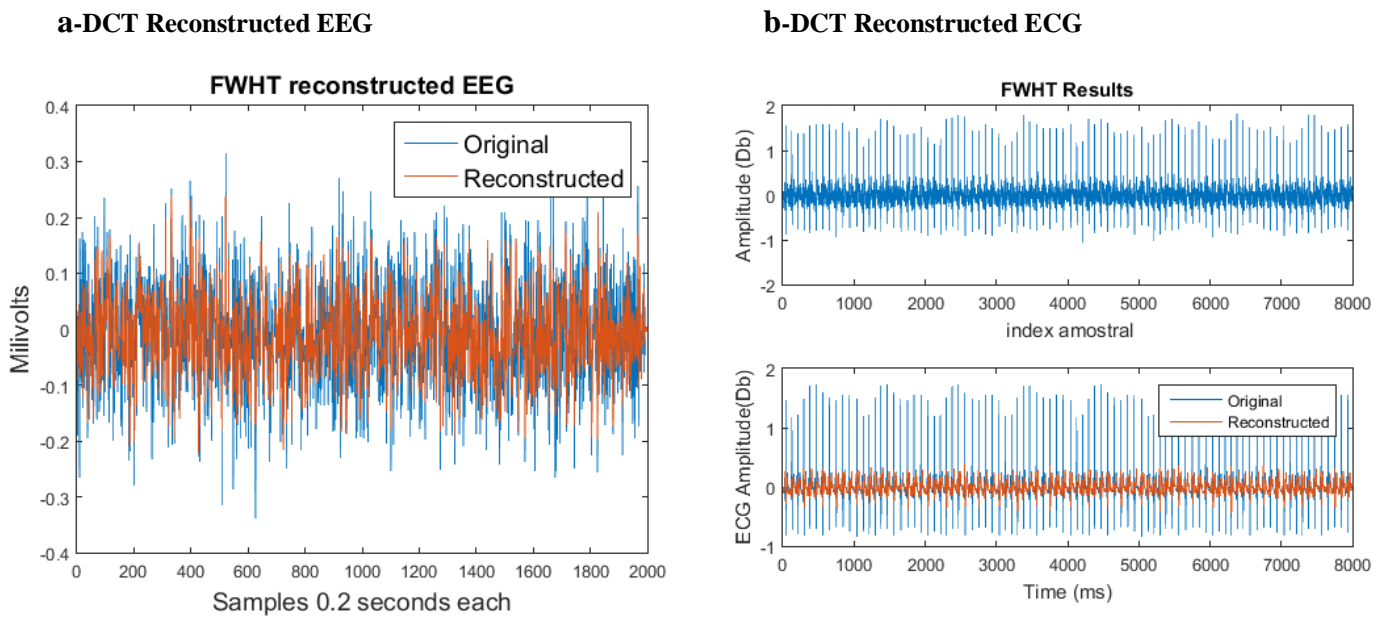
c-ECG WHT Coefficients



Source: Authors.

In the Figure 6, are showed the result obtained after the signal passes through the FWHT, being converted into WHT coefficients, or Walsh functions, with that it's possible to use the IFWHT to obtain a reconstructed signal.

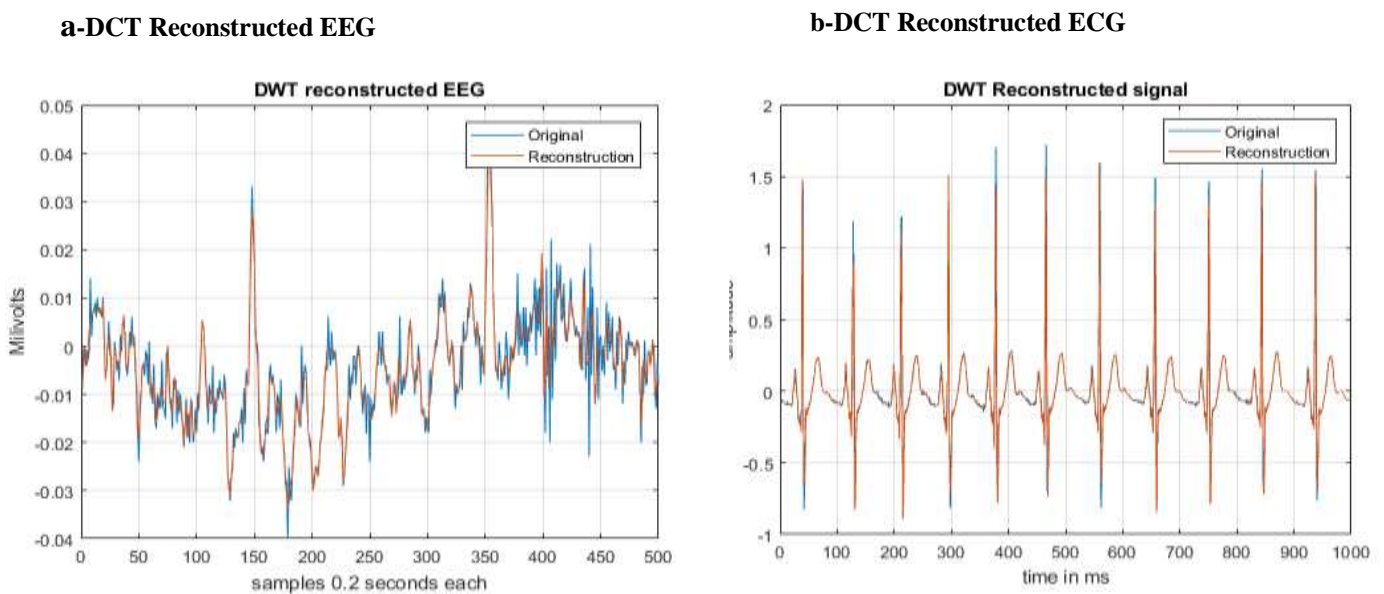
Figure 6



Source: Authors.

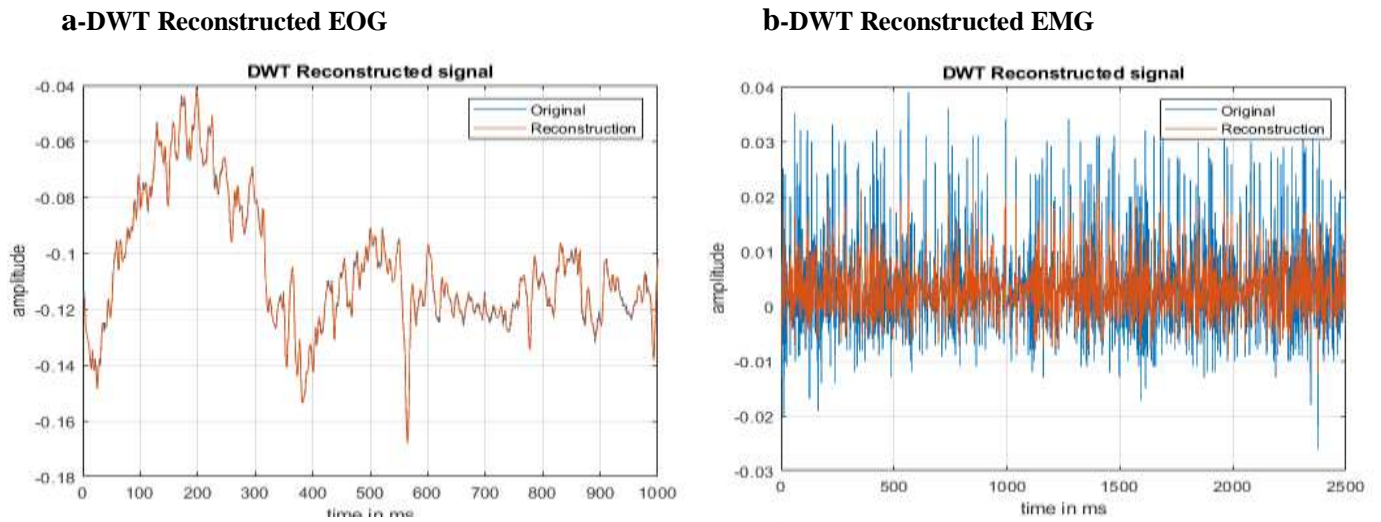
In the Figure 7, is showed graphically the original and the reconstructed signal who was tested with the DWT, graphically it's possible to see a little difference between each signal showing that the DWT is a precise transform.

Figure 7



Source: Authors.

Figure 8



Source: Authors.

On the Table 1, are exemplified the results of the statistical methods applied on the DCT reconstructed signal.

Table 1 - EEG Applied Discrete cosine Transform.

| Transform | Test | Value |
|-----------|------|-----------|
| DCT | PSNR | 24.397133 |
| DCT | SNR | 17.035322 |
| DCT | MAE | 0.001603 |
| DCT | MSE | 0.000004 |

Source: Authors.

On

the

Table 2, are exemplified the results of the statistical methods applied on IFWHT reconstructed signal.

Table 2 - EEG applied Fast Walsh Hadamard Transform.

| Transform | Test | Value |
|-------------|------|-----------|
| FWHT | PSNR | 13.351736 |
| FWHT | SNR | 3.380488 |
| FWHT | MAE | 0.053888 |
| FWHT | MSE | 0.004512 |

Source: Authors.

On the Table 3, are exemplified the results of the statistical methods applied on the DWT reconstructed signal.

Table 3 - EEG applied Discrete Wavelet Transform.

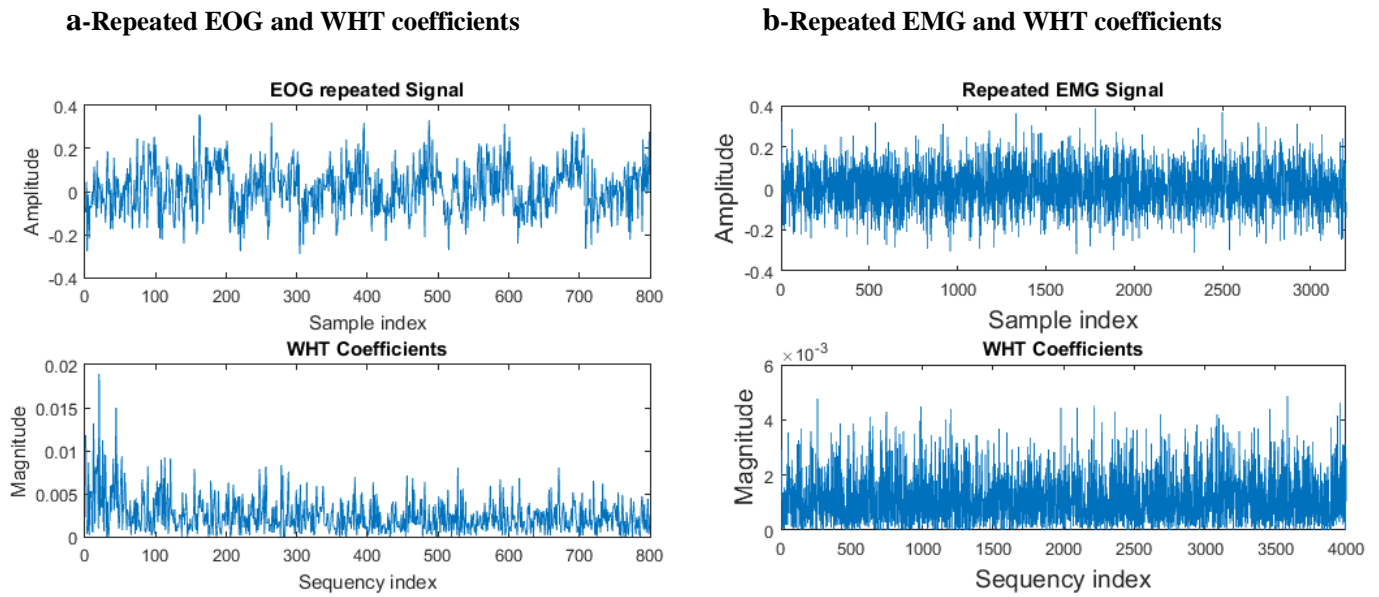
| Transform | Test | Value |
|------------|------|-----------|
| DWT | PSNR | 21.695940 |
| DWT | SNR | 10.090911 |
| DWT | MAE | 0.002685 |
| DWT | MSE | 0.000014 |

Source: Authors.

On the Table 3, are exemplified the results of the statistic methods applied on the DWT reconstructed signal.

In the Figure 9(a), are showed an 8x repeated EOG and the WHT coefficients of it, with that it's 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 Figure 9(b), but with the EMG, also is showed its WHT coefficients.

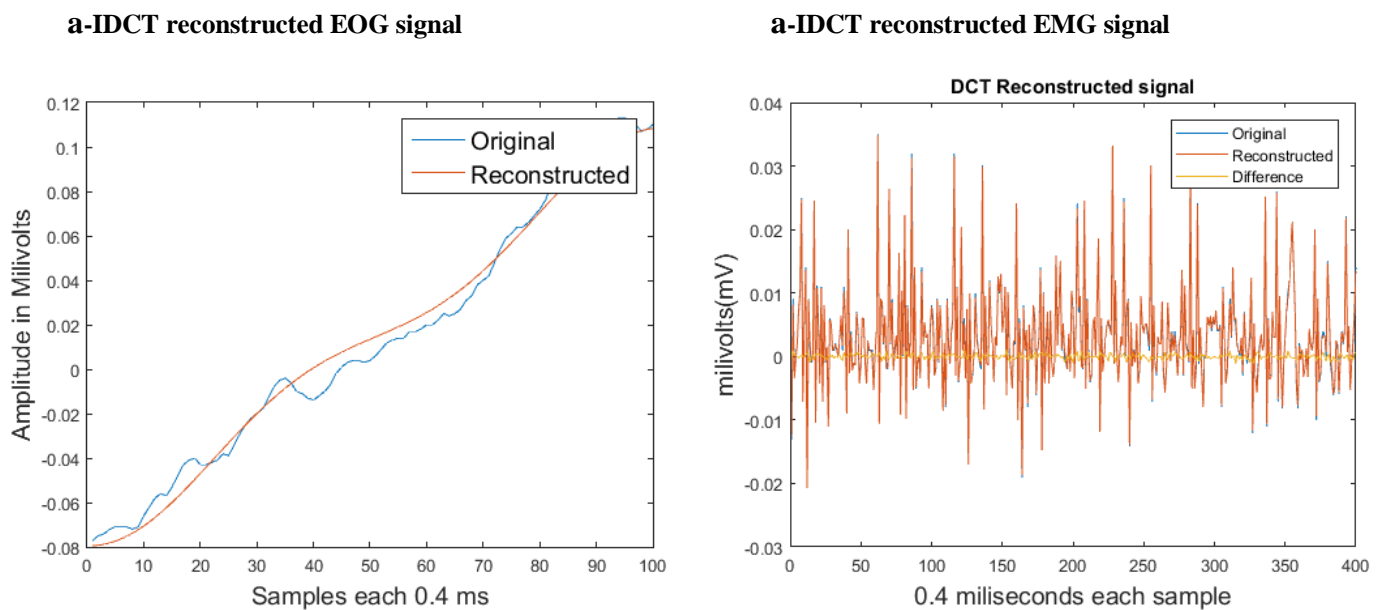
Figure 9



Source: Authors.

In the Figure 10(a) and Figure 10(b), is showed graphically the original and the reconstructed by IDCT signals, 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.

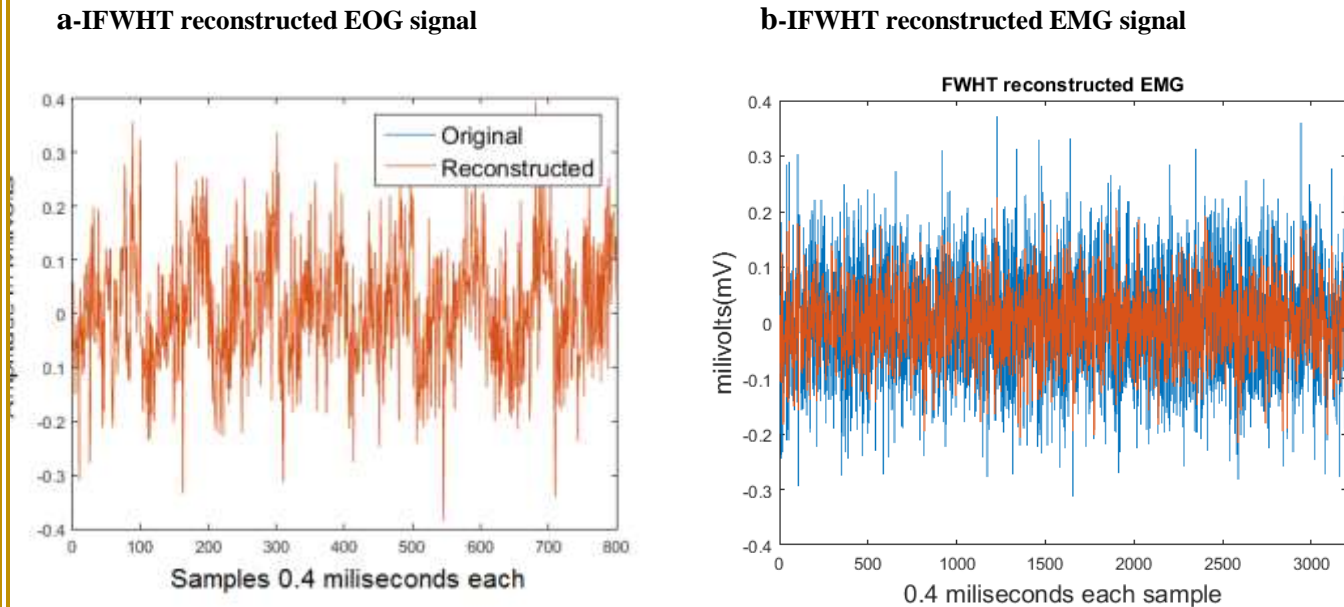
Figure 10



Source: Authors.

In the Figure 11(a) and Figure 11(b), are showed the result obtained after the signals passes through the FWHT, being converted into WHT coefficients, or Walsh functions, with that it's possible to use the IFWHT to obtain the reconstructed signals.

Figure 11



Source: Authors.

On the Table 4, are exemplified the results of the statistic methods applied on the DCT EOG reconstructed signal.

Table 4 - EOG applied Discrete Cosine Transform.

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

Source: Authors.

On the Table 5, are showed the results of the statistic methods applied on IFWHT EMG reconstructed signal.

Table 5 - EOG applied Fast Walsh Hadamard Transform.

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

Source: Authors.

On the Table 6, are exemplified the results of the statistic methods applied on the DCT reconstructed EMG signal.

Table 6 - EOG applied Discrete Wavelet Transform.

| Transform | Test | Value |
|-----------|------|-----------|
| DCT | PSNR | 35.542825 |
| DCT | SNR | 44.000589 |
| DCT | MAE | 0.000531 |
| DCT | MSE | 0.000000 |

Source: Authors.

Table 7 - EMG applied Discrete Cosine Transform.

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

Source: Authors.

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

Table 8 - EMG applied Fast Walsh Hadamard Transform.

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

Source: Authors.

Table 9 - EMG applied Discrete Wavelet Transform.

| Transform | Test | Value |
|-----------|------|-----------|
| DCT | PSNR | 16.201291 |
| DCT | SNR | 2.831526 |
| DCT | MAE | 0.004285 |
| DCT | MSE | 0.000036 |

Source: Authors.

As described early on the paper in this tables is possible to view the results of the statistics the errors are different for each transform and on the above figures is possible to see the difference of the signal reconstructed compared to the noisy version of itself.

4. Final Considerations

In a direct comparison between the above-mentioned transforms, Is Proven that the signals behavior is different to each transform, proving with the statistics that different transforms work differently on each type of biomedical signals, taking as example the ECG data analyzed, the FWHT obtained advantage because the reconstructed signal approached the original signal and its compression was much more efficient. after the comparison had a low difference, to the point of being negligible, we take the PSNR as an example, the FWHT resulted in 24.7, while the DCT had 25.2, a negligible difference.

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.

Those and more statistic results can be observed on the tables, proving with the

statistics that different transforms work differently on each type of biomedical signals, 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.

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