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ANALYZING EYE MOVEMENTS AND ITS EOG SIGNALS USING WALSH TRANSFORM

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Abstract:
The Walsh Transform was used in this research to extract and study the EOG signal of eye movements and its features. Four types Of EOG signals were measured, vertical eye movements (UP, down) Horizontal eye movements (Left and right). The measured EOG signals were filtrides then transformed using WHT and then reconstructed. A measurement system built using Arduino-like OLIMEX 328 microcontroller with two EMG shields.

Keywords: EOG, Walsh transform, Eye movements, feature detection, frequency spectrum.

1. Introduction:

The Walsh-Hadamard transform (WHT) is a suboptimal, non-sinusoidal, orthogonal transformation that decomposes a signal into a set of orthogonal, rectangular waveforms called the Walsh functions, for an application of this process see (Manish) [1].

The transformation has no multipliers and is real because the amplitude of Walsh or (Hadamard) functions has only two values, +1, or -1, detailed in (Hilary) [2].

The idea of using the Walsh spectrum can be salvaged by posing a power estimation problem in the context of stochastic noise theory. When random noise is present in a received signal, as used by (Welch) [3].

In general, there ben several popular signal detection methods for spectrum sensing such as energy detection, coherent detection (matching filter), and feature detection.

The energy and coherent detectors are simple and effective, but they cannot detect weak signals at a very low signal-to-noise rate (SNR), therefor for such cases feature detectors will be more reliable, as described by (Yang) [4], therefore the Walsh transform-based feature detector will be sufficient for this research.

The EOG measured in this research is processed by Walsh transform in which the signal is transformed into a sequence domain and compared with the threshold to decide the existence of a useful signal.

2. Eye Movements:

Eye movement characteristics have the potential to reveal a lot about our daily life. This includes information on visual tasks. Because we use our eyes in almost everything that we do, it is conceivable that eye movements may provide a useful information source for activity recognition, see (Andreas) [5].

There are three basic eye movement types that can be easily detected by EOG and were explained by (Bulling) [6]:

2.1 Saccades: The simultaneous movement of both eyes is called a saccade. The duration of a saccade depends on the angular distance the eyes travel during this movement the so-called saccade amplitude. Typical characteristics of saccade eye movements are 20 degrees for the amplitude and 10 ms to 100 ms for the duration.

2.2 Fixations: Fixations are the stationary state of the eyes during which the gaze is held upon a specific location in the visual scene. Fixations are usually defined as the time between two saccades. The average fixation duration lies between 100 ms and 200 ms.

2.3 Blinks: It is the regular opening and closing of the eyelids. The average blink rate varies between 12 and 19 blinks per minute. It is influenced by environmental factors such as relative humidity, temperature brightness, but also by physical activity. The average blink duration lies between 10ms and 400ms.

In order to generate an eye movement along any axis, there are three opposing pairs of muscles attached to the globe of the eye. These antagonizing muscle sets work to move the eye horizontally and vertically for the rotational movement of the eyeball, for more information see (Veena) [7].

3. EOG Signal Characteristics:

Electrooculography (EOG) is a test to measure the electrical response of the-light sensitive cells (rods and cones) and motor nerve components of the eye. This involves placing electrodes on the skin near the eye, as shown in fig. (1), see (Adithya) [8].

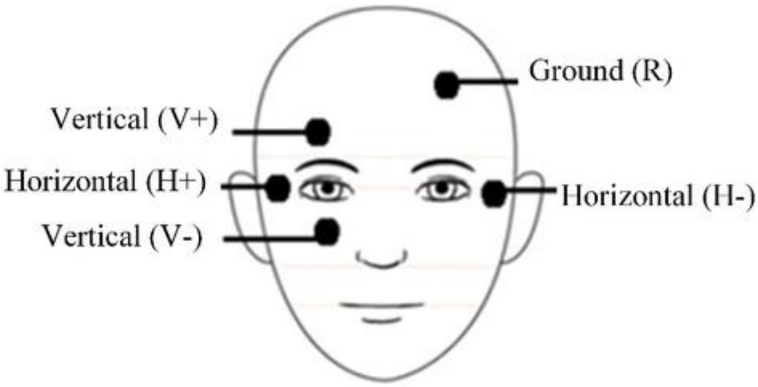


Fig. (1) electrodes placed for EOG measurements

EOG signals appear when someone moves his or her eyes, and they can be used for manipulation control, see (Damina) [9].

The EOG is the electrical signal that corresponds to the electrical potential difference between the retina and also the cornea of the eye.

This difference is because of the fact that the occurrence of metabolic activities in the corneal region is higher than that in the retinal area, explained by (Kavitha) [10].

The magnitude of the corneoretinal potential of the electrooculogram output is typically in the range of 90-100 µV and is an instantaneous value that varies linearly with the eyeball position. This linear variation is 5-20 µV, (Aditha) [8].

4. Walsh-Hadamard Transform:

The basis vectors of the discrete Hadamard and the discrete Walsh-Hadamard transforms consist of the values α± just like the Walsh functions, both transforms are unitary. Basically, they differ only in the order of the basis vectors.

We have:

$$y = Hx \qquad (1)$$

$$X = Hy$$

where X denotes the signal, y is the representation, and H is the transform matrix of the Hadamard transform. H is symmetric and self-inverse:

$$H^T = H = H^{-1} \qquad (2)$$

Recursively, we define the 1x1 Hadamard transform H0 by the identity H0=1, and then define Hm for m>0 by:

$$Hm = \frac{1}{\sqrt{2}}\begin{pmatrix} Hm-1 & Hm-1 \\ Hm-1 & Hm-1 \end{pmatrix} \qquad (3)$$

The Forward and inverse Walsh transform pair of a signal X(t) of length N (see Martins) [11] are:

$$y_i = \frac{1}{N}\sum_{i=0}^{N-1} x_i \, WAL(n, i) \qquad n=1, 2, \ldots\ldots, N-1 \qquad (4)$$

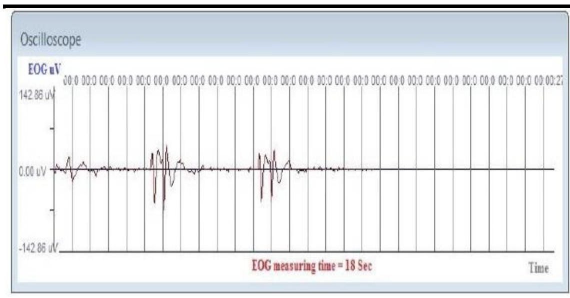
$$xi = \frac{1}{N}\sum_{i=0}^{N-1} yi\, WAL(n, i) \qquad n=1, 2, \ldots\ldots.., N-1 \qquad (5)$$

5. Results and Discussion:

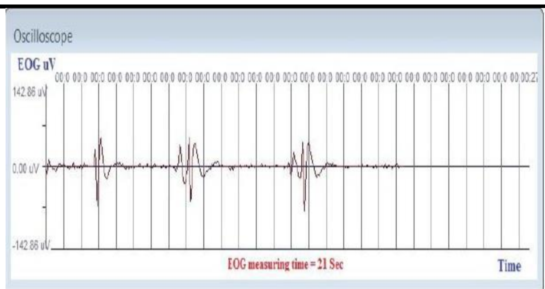
Often, it is necessary to record EOG signals with multiple time slots to cover different measurement environments and to collect sufficient data to be used for the feature extracting and analyzing process.

The Walsh-Hadamard transform is suitable for fast computation of Walsh-Hadamard coefficients, and efficient signal reconstruction.

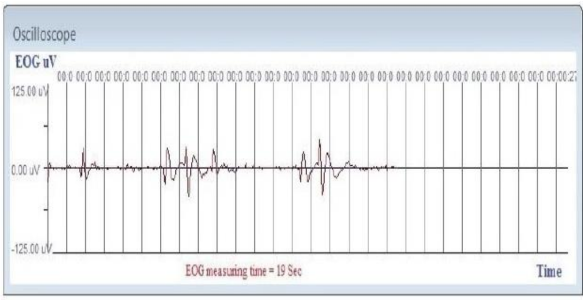
An OLIMEX 328 with two EOG shields used to measure the EOG signals, the four eye movements Vertical (UP & Down) and Horizontal (Left & Right) are shown in fig, (2).



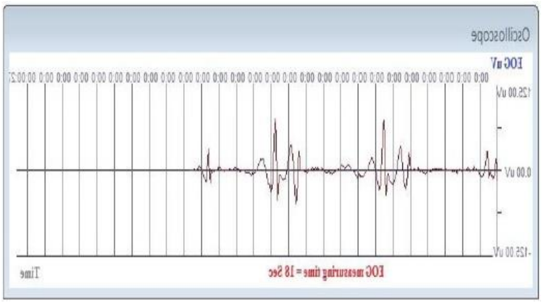
EOG VU



EOG VD



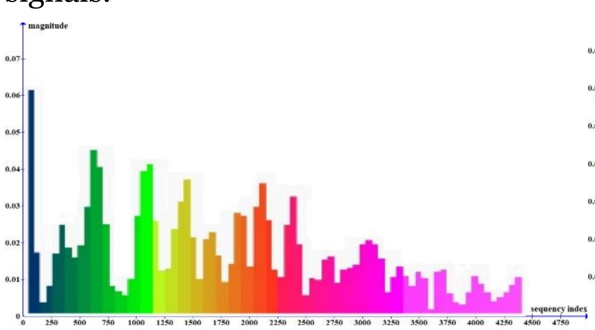
EOG HL



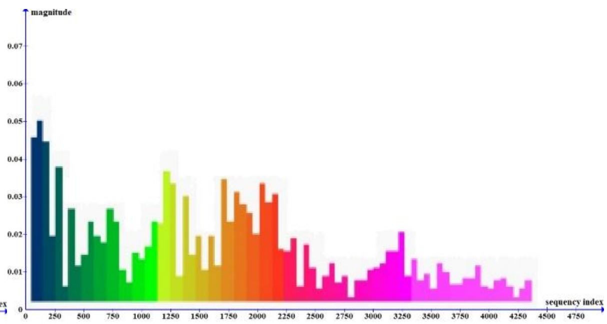
EOG HR

fig. (2) Measured EOG signals (vertical UP & down, Horizontal Left & Right).

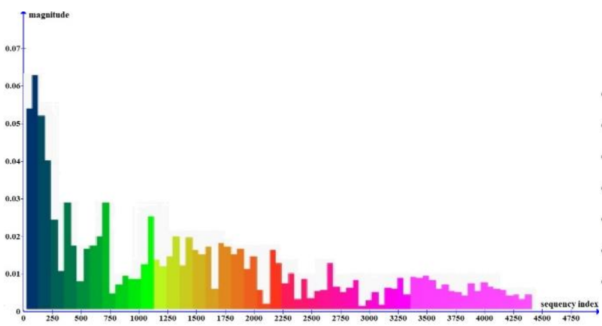
The calculated Walsh-Hadamard coefficients and the plot of the measured EOG signals are shown in fig. (3), the plots show that the most effective components of the signal is the lower sequency values, these values was used to reconstruct the EOG signals.



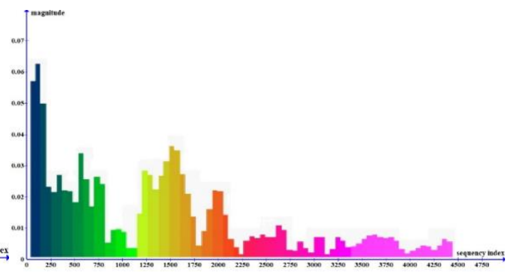
EOG VU



EOG VD



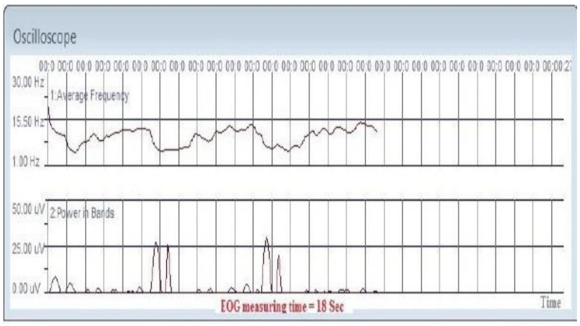
EOG HL



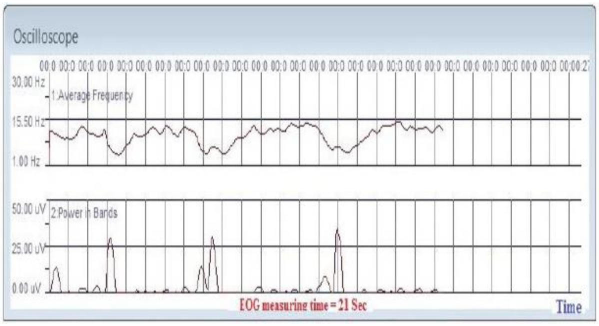
EOG HR

Fig. (3) WHT of the measured signals

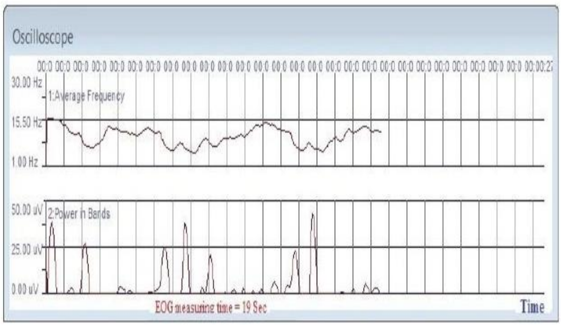
The power envelope of the reconstructed EOG signals is shown in fig. (4), and the results show the efficiency of WHT in processing the EOG signals.
These results can be used for eye movements analysis and activity recognition, this is will be satisfied through following the EOG signals variations and then compare it with a previous data base.



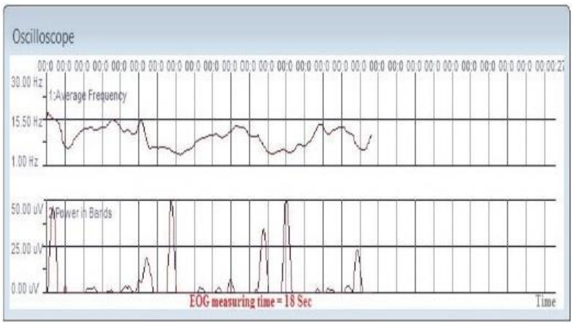
EOG VU



EOG VD



EOG HL



EOG HR

Fig. (4) Power Envelope of the reconstructed EOG signals

5. Conclusion:

This research presents how to use the WHT to analyze, process, and reconstruct the EOG signals of vertical (up& down) and Horizontal (Left & Right) eye movements from raw EOG signals, the resultant signals can be used to recognize different activities of eye movement, also the result can be used for control purposes.
Measuring EOG signals in multiple time slots and different activities of eye movements was very useful and important to collect data to have good and accurate results.
Analysis of EOG signals depends on frequency and sequency domain will much helpful to construct an efficient control system based on using Bio signals.

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