Lab 3 Report: Data Acquisition and Analysis of EOG Signals using Biosignalplux

Course: EEEE 536.60L1 and EEEE 636.60L1 – Biorobotics/Cybernetics

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1) Manifesto

Both team members actively worked on every section of this lab report. The structure of which collaboration was very efficient and led to high standards for all tasks being completed. We made sure that the lab questions and tasks were divided equally between both of us so that there is fairness and efficiency. The responsibility for specific set of exercises and sections of the report was taken by each of the team members.

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2) Introduction

Electrooculography (EOG) stands as a biomedical methodology which detects the corneo-retinal standing potential in human eyes. EOG serves as a standard technique for eye movement tracking since it finds essential applications in human-computer interaction and neurofeedback along with assistive technologies. The experiment utilizes the biosignalsplux EOG sensor in combination with the OpenSignals software to obtain and process EOG signals which originate from eye movements including looking left/right and up/down and blinking. Acquiring hands-on knowledge in biosignal acquisition and analysis required setup activities combined with code development during which we learned the integrated physiological and technical aspects of the process.

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3) Theory

Both electrical charges within the human eye structure demonstrate dipolar characteristics because the positive charge resides in the cornea and the negative charge appears in the retina.

Shifts of the eyes create equal changes in electrode-generated potential differences among devices positioned near the eyes.

- **Horizontal Movement:** The electrodes should be placed on the left side and right side of each eye. When eyes glance toward one direction the voltage changes because the cornea proximity and retina distance mirror the direction of gazing.
- **Vertical Movement:** The electrode markup system positions hardware on the upper and lower portion of the eye. A positive electrical alteration occurs when someone looks upward yet downward gaze results in a negative change.
- **Blink Detection:** Causes the EOG signal to show sudden spikes that stand out from continuous gaze signals due to their short duration.

Through bipolar differential configuration the biosignalsplux EOG sensor enhances the voltage difference and eliminates noise from the signal. This sensor suits the observation of delicate eye movements due to its 2040 gain factor which provides excellent signal-to-noise ratio and precision at medical standards.

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4) Methodology

1. Software and Environment Setup

- Download of OpenSignal Software took place through PLUX website.
- The EOG.ipynb Jupyter notebook was uploaded to Google Colab to perform evaluation of the live data.
- Installed required Python libraries:
    - **!pip install opensignalsreader biosignalsnotebooks**

2. Electrode Configuration

- **Reference Electrode:** An electrically neutral positioning of the reference electrode serves as best practice placement on the forehead or mastoid areas.
- **Vertical EOG:** This will have electrodes situated above and beneath the eye.
- **The horizontal EOG:** electrodes are positioned at the outer area and the inner area of the eye canthi.

3. Data Acquisition

- Powered on biosignalsplux Solo device.
- After opening OpenSignals I selected my device before enabling the application.
- The system operates through RAW input because the EOG dedicated mode is not supported.

- Recorded a session involving:
    - Horizontal gaze shifts (left/right)
    - Vertical gaze shifts (up/down)
    - Blinking

4. Data Processing & Visualization

The software allowed data loading through both .txt and .h5 file formats:

- **from numpy import loadtxt**
- **import biosignalsnotebooks as bsnb**

- The software created time vectors based on the measurement sample rate.
- Used bsnb.plot() to visualize signals.
- Signal filtering and interpretation techniques became visible by adding artificial noise and baseline shift to the data.

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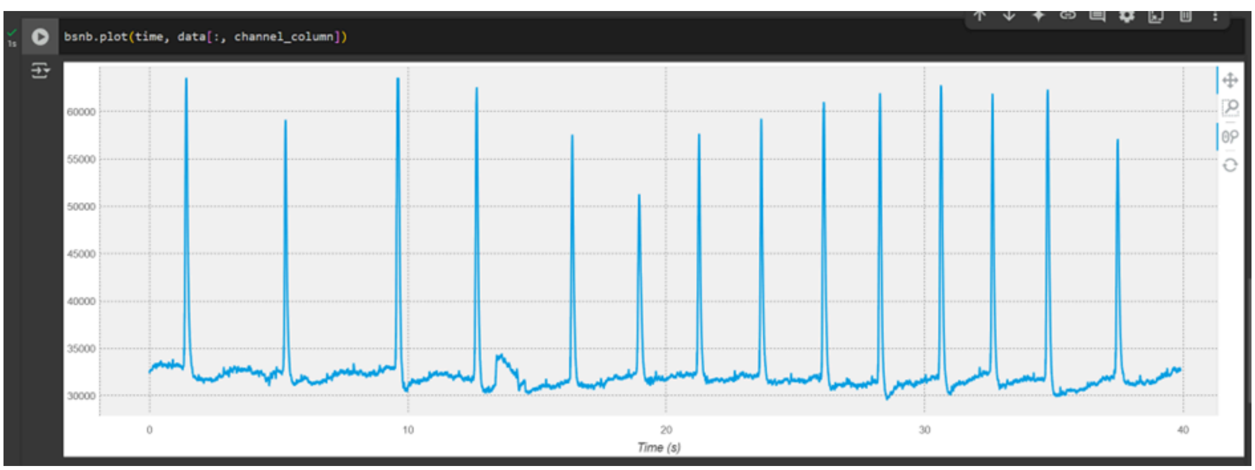
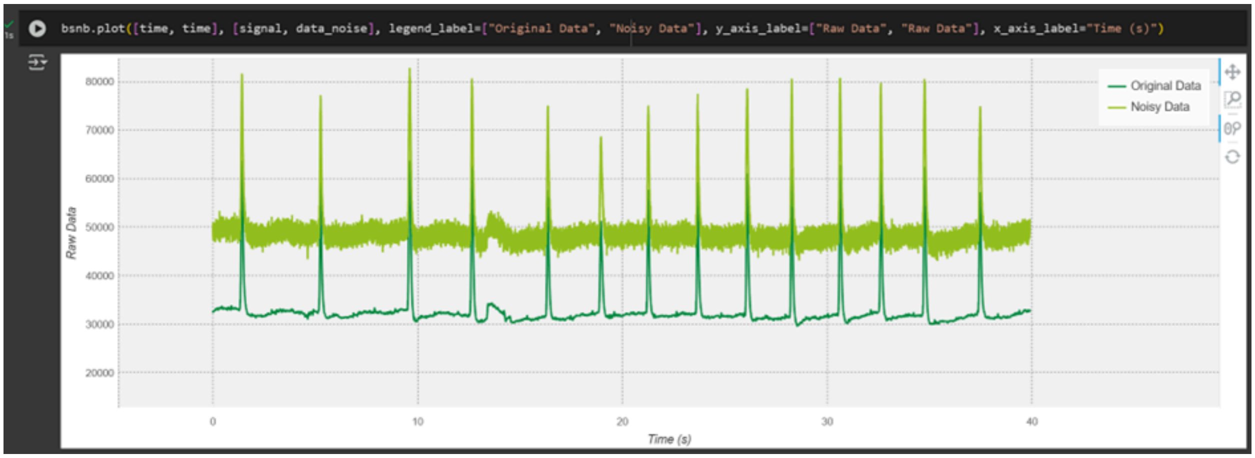
5) Results and Discussion

Blinking:





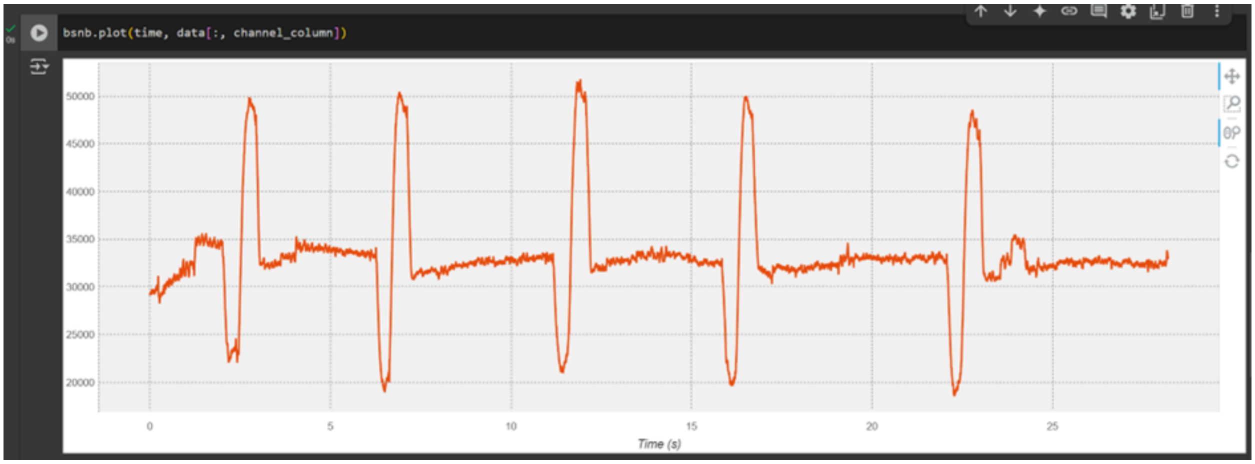
Blinking – Graph 1 vs Graph 2

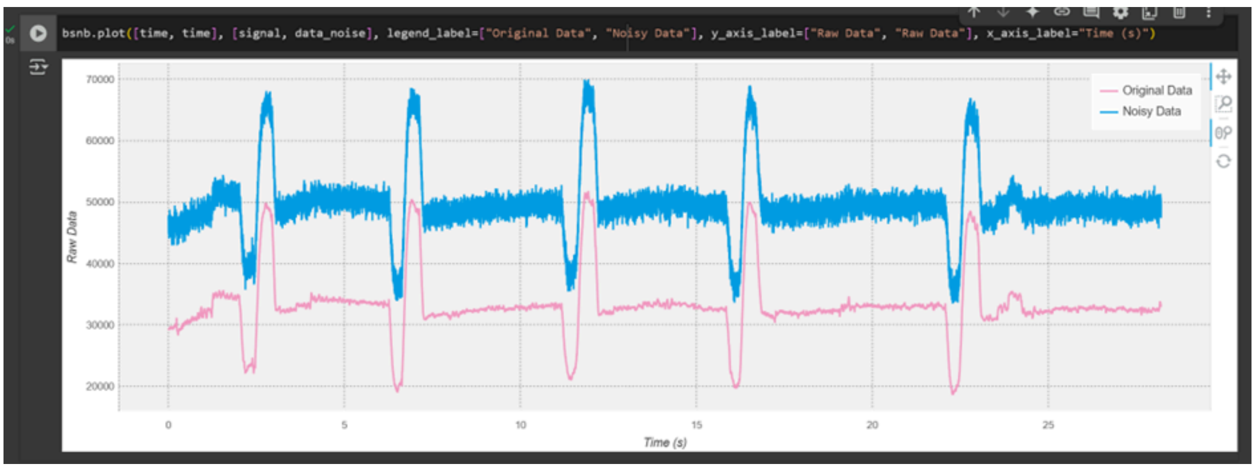
Graph 1 (top image) The waiting period contains a standard blinking EOG signal that produces distinct yet short spikes throughout the measurement duration. Clean peaks within the recording represent well-detected blinks that show minimal background noise. The peaks appear vertically on the chart because eyelid movements occur rapidly to generate swift changes in corneo-retinal potential.

The lower graph in Figure 2 indicates a signal that contains some added background noises despite featuring blink signals. Even though the peaks remain visible their shape has become rounded while the baseline shows some variations after each eyelid movement. The recording shows both slight movement artifacts and irregularities in blink patterns.

Comparison: The blinking behavior shows successful recording in both graphs yet the clear peaks and stable measurements in Graph 1 indicate optimized environmental factors or sensor position. The data in Graph 2 provides useful outcomes yet needs light management or data processing steps for exact research analysis. The combined evidence from these graphs demonstrates that EOG remains dependable for detecting blinks regardless of the testing environment.

Horizontal:





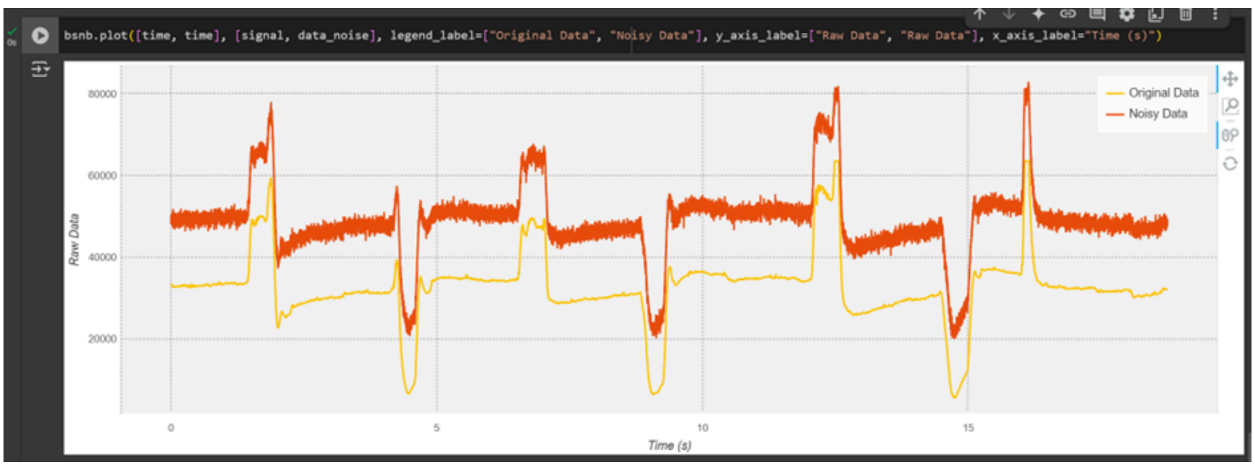
Horizontal Eye Movement – Graph 1 vs Graph 2

Graph 1 presents data points that follow a sinusoidal shape because the eyes move right and left. The waveform maintains a stable depth of change across each swing while the wave distances show that movements followed a regular pattern. The observation of proper horizontal electrode placement together with user test compliance is verified through this pattern.

The recording in Graph 2 demonstrates inadequate symmetry together with a noticeable baseline shift. The observed horizontal movements exist in this waveform yet it does not achieve the organized symmetry of Graph 1. The measured eye movements show additional slight variations between the speeds or distances of motion possibly due to incorrect electrode connections.

Comparison: The movement patterns in Graph 1 are characterized by clear left-right movements that distinguish it from other traces. The information from Graph 2 becomes helpful through its data presentation yet the measurements show possible changes in movement intensity or duration from the subject. The data from both experiments proves that EOG technology can effectively track eyeball movement although Graph 1 provides the most accurate measurements.

Vertical:



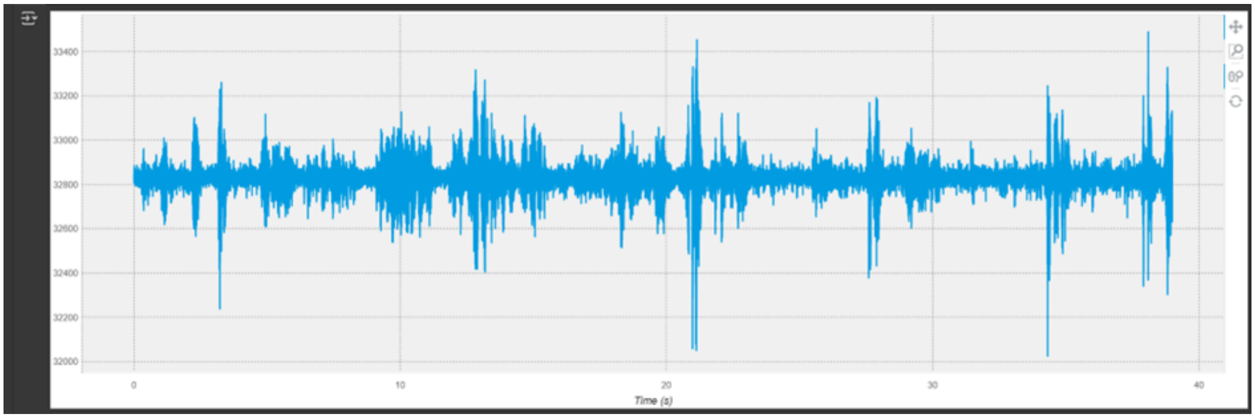
Vertical Eye Movement – Graph 1 vs Graph 2

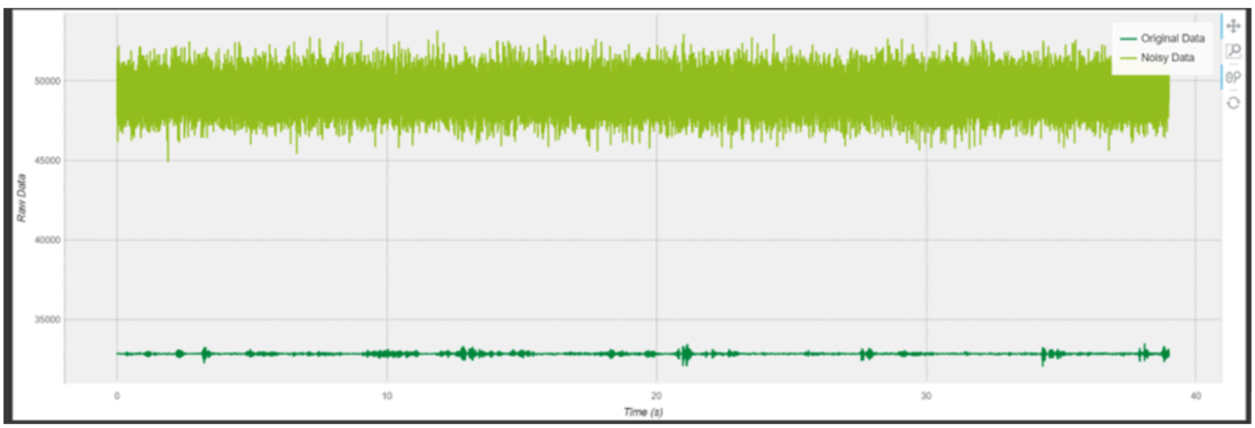
Graph 1. The vertical movement graph presents regular oscillations that display separate peaks and troughs corresponding to upward and downward eye motions. A regular waveform pattern extends across the measurement while its amplitude exceeds values found in the horizontal measurements due to increased sensitivity in the vertical axis or larger movements in the user's eyes.

Graph 2 exhibits a comparable pattern with reduced amplitude along with irregular wave spacing intervals. The peaks transit between each other more subtly in this graph than in previous data collections probably because of muted eye movements or reduction of sample quality.

Comparison: The signal strength and rhythms appear more pronounced in Graph 1 compared to Graph 2 when detecting vertical movements among the graphs. The detection of vertical movement remains evident in Graph 2 although it requires further development to be suitable for real-time applications. The data shows that switching minor elements of behavioral or setup configuration affects the signal's accuracy.

In class:





In-Class Signal – Graph 1 vs Graph 2

Normally recorded EOG signals during classroom activity appear in Graph 1 (top) in this category. The waveform contains complex and unstructured data because it includes both blinks and subtle movements as well as background noise. Ear learners can detect blinking activities through brief spikes within the signal but true eye movements and environmental noise generate most signal activity.

The bottom part of Graph 2 presents eye signal data with reduced baseline influence along with more noticeable blink waveforms. Although extensive noise pertains throughout the recording there are brief stretches of improved noise quality which could relate to eye movement.

Comparison: The two charts display the untreated EOG signals that emerge from normal field settings. The data in Graph 1 shows higher levels of instability when compared to the partly organized data in Graph 2. The analysis demonstrates how difficult it is to read messy data and how crucial data preprocessing duties for authentic EOG analytics procedures. These results duplicate the data patterns that actual attention tracking systems would encounter during regular operation.

Full Signal Comparison: Blinking vs Horizontal vs Vertical vs In-Class

This laboratory experiment uses EOG signals to show different representations of eye movement patterns and thereby highlights both advantages and disadvantages of electrooculography in specific execution conditions.

- Blink signals produce the most observable waveform among all recorded signals. Blinks create distinct high-amplitude waves that last for a short timeframe thus making them easy to detect and separate from other signals. The signal operates at a low frequency rate with minimal activity overlap which makes it the best pattern for analysis. Evaluating blinks serves as an outstanding method to monitor real-time fatigue while assisting communication and monitoring attention.
- The pattern of smooth periodic horizontal eye movements each presents one wave for both left and right gazing motions. The movements generate waveforms that maintain steady frequencies together with moderate amplitude levels if the motion remains consistent. The gaze tracking system uses Horizontal EOG to permit users to control screens through eye movements.
- Eye movements that occur in the vertical plane resemble horizontal movements but display increased amplitude together with well-proportioned waveforms. Electrode alignment above and below the eye as well as robust muscle activity during vertical eye movements might contribute to this effect. The performance quality of vertical EOG signals enables its use in multiple directional input devices or examinations of eyesight movements.
- In-Class records spontaneous uncontrolled eye motion patterns that occur in an actual physical setting. The signal consists of eye blink patterns together with minimal eye movements as well as environmental sounds. The signal presents an unorganized and disordered pattern with many frequency ranges and diverse amplitudes. Despite lacking standardized methodological characteristics it provides essential insights on real-life operation necessary for developing functional adaptive EOG technologies.

Feature	Blinking	Horizontal Movement	Vertical Movement	In-Class Signal
Pattern	Sharp spikes	Smooth waves	Smooth waves	Mixed/chaotic
Duration	Very short	Moderate	Moderate	Variable
Amplitude	High	Medium	Slightly higher	Varies (low to high)
Regularity	High	High	High	Low
Noise	Low	Low to moderate	Low	High
Ease of Analysis	Very easy	Easy	Easy	Difficult
Best Use Case	Fatigue, blinking detection	Eye tracking interfaces	Accessibility, vertical gaze tracking	Real-world attention and activity monitoring

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Final Reflection

The analysis shows that separate signals within EOG technology serve independent functions for its wider applications. The most distinguishable EOG signal emerges from blinking activities yet horizontal and vertical movements supply directional feedback through steady waveform patterns. The in-class recording stands as the most crucial signal for system development because it shows the outside performance of EOG detection in non-lab conditions despite its complexity. Various signal types when combined offer comprehensive bioelectrical data which serves purposes such as interaction, diagnostics and behavioral tracking activities.

B)

We decided to include all the screenshots as we felt like that all figures and codes were necessary to include.

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6) Picture of the EOG Band Attached

 

7) References

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