EEG acquisition validation through SSVEP by using actiCHamp and OpenViBE - Towards a BMI for upper-limb rehabilitation

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Abstract— **The actiCHamp system from Brain Vision®is a modular amplifier used to acquire electrophysiological signals, such as electroencephalogram (EEG). This study aims to provide a detailed guide for using actiCHamp together OpenViBE, in order to build a Brain-Machine Interface (BMI) for upper-limb rehabilitation purpose. This work encompasses general considerations on EEG, steps to install and use both Brain Vision Recorder and OpenViBE. Furthermore, recommendations to enhance and verify the skin-electrode impedance by using alcohol, gel, the Brain Vision Recorder and actiCHamp, and record signals employing actiCHamp and OpenViBE. To validate the quality of the collected data, Steady State Visually Evoked Potentials (SSVEPs) were employed, processing the signals in Python through a band-pass filter and the fast Fourier transform to further analyses in the frequency domain. As a result, power peaks at the SSVEP stimuli were observed, confirming the integrity of the recorded signals.**

Keywords— **ActiCHamp, Brain-machine interface, EEG, SSVEP, OpenViBE.**

I. INTRODUCTION

A Brain-Machine Interface (BMI) measures the brain activity and translates it into artificial output for people with severe neural impairments to control or command end-applications, such as functional electrical stimulation, robotic exoskeletons, smart walkers, virtual keywords and serious games. Particularly, these systems provide an alternative pathway with artificial output that replaces, restores, enhances, supplements, or improves natural central and peripheral mechanisms [1, 2].

To acquire the brain activity signals on the scalp's surface in BMI systems, the EEG have been widely used because of its non-invasiveness, low-cost, portability, usability and high temporal resolution. Furthermore, brain rhythm oscillations and events, such as mu and beta rhythms, event-related desynchronization/synchronization (ERD/ERS) and motor-related cortical potentials (MRCPs), produced during real and imagery motor tasks can be measured for analysis and classification purposes by using EEG [3]. These advantages make EEG popular for clinical and research purposes [4–6].

The EEG signal has a low signal-to-noise ratio, which challenges the analysis and classification of motor rhythms with very low amplitudes, such as mu (8-12 Hz) and beta (13-30 Hz). To address this issue, various EEG devices have been widely used in motor intention recognition-based BMI systems [7–9].This study only focuses on actiCHamp [1] from BrainVision®.

The objective of this study is to provide a detailed guide for using actiCHamp together OpenViBE, in order to acquire EEG data in a BMI for upper-limb rehabilitation. The quality of the collected EEG data was verified by using spectral analysis after applying Steady State Visually Evoked Potentials (SSVEPs) in a healthy volunteer. In short, SSVEPs is a neurophysiological phenomenon in which the brain evokes responses or wave oscillations at the main frequency and its harmonics of a visual stimulus [10]. This work is addressed mainly for beginners and advanced practitioners, facilitating their learning the first times using efficiently actiCHamp together OpenViBE, recording data with quality.

II. MATERIALS

The actiChamp amplifier and BrainVision Recorder software were utilized to acquire brain signals from EEG electrodes, and also verify the skin-electrode impedance, respectively. The actiChamp records multi-channel EEG using a total of 32, 64, 96, 128, and 160 channels. Additionally, it features 8 additional auxiliary inputs (referred to as AUX), enabling the simultaneous acquisition of various electrophysiological signals. The BrainVision Recorder is used with the actiChamp amplifier, offering various functionalities, such as a friendly tool for checking the skin-electrode impedance.

[1] www.brainvision.com/actiCHamp.html

For this study, a 32-electrode system (actiCAP Xpress from Brain Products) and an electroconductive abrasive gel (EasyCAP) were used for reducing impedance with the skin. The OpenViBE Designer and OpenViBE Acquisition Server applications were employed for the acquisition and recording of raw signals.

Regarding the experimental protocol, an electronic circuit was assembled on a prototyping board (breadboard). In this circuit, white and red LEDs were arranged in series with a 27 Ω resistor. These LEDs were activated by a Minipa MFG-4202 signal generator, capable of generating sine, square, and triangular waveforms with analog potentiometer adjustment. The signals were measured using a Tektronix oscilloscope, model TDS-2002B, to verify their correct frequency.

III. METHODS

A. Interaction between actiCHamp and OpenViBE for EEG

A1 Installing Brain Vision Recorder and OpenViBE

Firstly, the user needs to extract the application files to the desired location on their computer. After downloading the latest version of Brain Vision Record from the Brain Products website, the storage directory is selected, and the downloaded files are unpacked.

Next, the user navigates to the folder where the files were extracted and locates the file named "Autorun". Upon finding it, a double-click is performed to open it. This results in the opening of the main menu of the Brain Vision Record installer.

To proceed, it is necessary to ensure that the license dongle (a USB drive containing the license) is properly connected to the user's computer. With the dongle connected, in the main menu, the user selects the option "Install BrainVision Recorder & Video Recorder". Then, the option "Install BrainVision Recorder" is located and clicked. The user waits until the installation is completed. During this process, the application is configured correctly in the system.

By following these steps, Brain Vision Record will be installed and ready to be used for impedance measurements.

A2 General Considerations about EEG

To acquire brain signals, it is recommended to pay attention to the user's guide for EEG cap preparation, and also inform the volunteer about the experimental protocol that will be carried out. The participant should feel comfortable throughout the data collection, and he/she should be informed, that, the experiment will be interrupted in case of any discomfort.

The number of EEG channels and their locations on the scalp is selected, according to the research interest. It is worth noting that a higher number of electrodes leads to richer data, but it also requires to spend more time preparing electrodes. The EEG preparation involves first the surface skin preparation on the scalp by cleaning the locations of interest, enhancing consequently the electrode's impedance keeping it below 10 kω. Therefore, it is crucial that participants have clean hair and face before the experiment, without using additives such as conditioner, styling gel, or makeup, as they can hinder proper data collection.

A3 Verifying the Electrode's Impedance using Brain Vision Recorder

The impedance check follows a step-by-step procedure to ensure the accuracy of the results. At the beginning of the procedure, it is necessary to connect the dongle and the actiCHamp to the computer. Then, the Brain Vision Record software must be run as an administrator to access the necessary functionalities. On the software's initial screen, it is important to access the "Configurations" option and select the appropriate amplifier, in this case, the "actiCHamp". This selection is made through the "Select Amplifier" menu. Next, in the "File" menu, the "New Workspace" option should be chosen to open a configuration window where the necessary adjustments will be made.

Within the configuration window, it is possible to proceed with the process. At this stage, it is important to use the "Scan for Amplifier" function to find and identify the amplifier connected to the computer. Additionally, the acquisition rate, number of channels, and specific channel to be used need to be defined. These configurations are made through the fields "Sampling Rate [Hz]," "Number of Channels," and "Reference Channel," respectively.

After completing all the necessary configurations, simply follow the instructions and finish the process by clicking on "Finish." On the software's initial screen, the "Impedance Check" option can be accessed through an illustration of a bar. This function will display the available channels and present a color scale indicating the level of impedance. By clicking on this option, Impedance Check, the "actiCHamp Window" will open, where the color scale can be adjusted under "Show Details."

Once all these steps are completed, the dongle and the Recorder software will no longer be needed.

A4 Signal acquisition using actiCHamp and OpenViBE

To perform signal acquisition, the OpenViBE Acquisition Server software must be run in administrator mode. Then, in the "Driver" option, the "Brain Products actiCHamp" device is selected. It is necessary to access the "Driver Properties" to define the number of channels and the desired acquisition rate, and then apply the settings. Finally, click on "Connect" and "Play" to start signal acquisition.

To prepare the scenario for visualization and data recording, the OpenViBE Designer software should also be run in administrator mode. Upon opening the scenario, a list of "Boxes" will be displayed on the right side of the interface. In this list, it is necessary to search and drag the following boxes into the scenario: "Acquisition Client," "Common Average Reference" (CAR), "Signal display," and "CSV File Writer." Then, proper connections between these boxes need to be made, as shown in the Figure 1.

The signal acquisition box should be connected to the CAR box, using the pink arrow to indicate the flow of the signal. The CAR box, in turn, should be connected to both the Signal display and the CSV File Writer boxes. When selecting the CSV File Writer box, it is possible to define the folder where the file will be saved and assign a name to the file. It is important to pay attention to renaming the file for each collection to avoid data overlap. Additionally, it is worth mentioning that there are other formats available for data recording besides the CSV format.

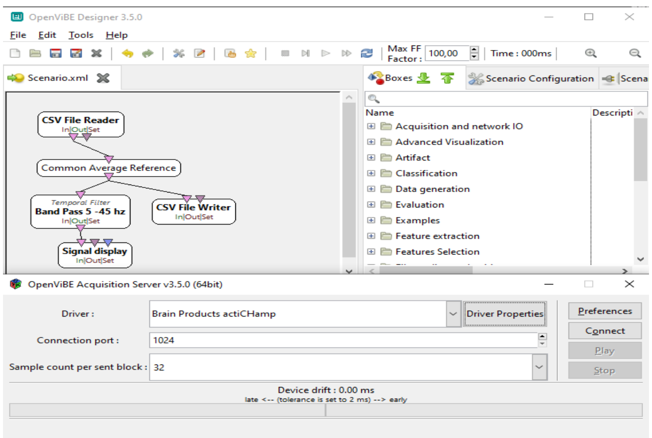

Fig. 1: Scenario for data acquisition in OpenViBE.

B. Protocol

The study included a 36-year-old adult male participant with no clinical complaints or medication use and normal or corrected-to-normal vision. The volunteer was comfortably seated to initiate skin and scalp cleansing using 70% alcohol. Subsequently, scalp exfoliation was performed using EasyCAP to maintain electrode contact impedance below 10 kOhms, and impedance measurements were obtained using the BrainVision Recorder. EEG signals were acquired using a 32-electrode cap prepared according to the international 10/20 system, with only 24 electrodes positioned as follows: FP1, FP2, F3, F4, FC3, FCz, FC4, C5, C3, C1, C2, C4, C6, CP3, CPz, CP4, P7, P3, PZ, P4, P8, O1, and O2. The reference (REF) and ground (GND) electrodes were placed at TP9 and TP10, respectively. EEG signals were acquired using the actiChamp amplifier in the frequency range of DC to 7500 Hz and sampled at 500 Hz. The signal recording was performed in openViBE using the method explained previously.

To deliver visual stimuli, a circuit was assembled using a breadboard, where LEDs were connected in series with a resistor and powered by a square wave signal at different frequencies generated by the generator. By using a square wave to power the LEDs, it was possible to make them blink. At the highest amplitude of the signal, the LED would light up, and at the lowest amplitude, it would turn off. Thus, it was possible to make the LED blink at the same frequency as the configured signal, meaning that by adjusting the frequency to 9 Hz in the square wave, the LED would blink 9 times per second. An oscilloscope was used to confirm the signal feeding frequency, allowing confirmation through Fourier transform analysis.

Based on the work by [11], stimuli were presented using two LEDs of different colors, red and white, at frequencies of 9 and 13 Hz. As shown in Figure 2, the LED circuit on the prototyping board was positioned in front of the volunteer in a dark room, and the volunteer was instructed to focus on the LED for two minutes for each of the four combinations of colors and frequencies. Additionally, a reference EEG signal was collected in the absence of visual stimulation, during which the volunteer was instructed to avoid thinking about anything and making sudden movements.

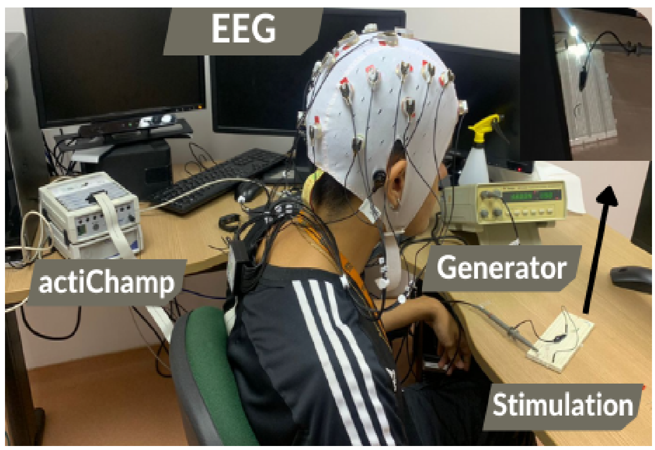

Fig. 2: Merely illustrative image of the data collection protocol.

IV. Results

The collected data was processed using the Python programming language. In order to visualize the frequencies of interest and reduce possible noise in the data, a second-order Butterworth bandpass filter was applied, with a cutoff frequency range between 8 Hz and 45 Hz. Subsequently, a Fourier transform was performed to decompose the signal in the time domain into its frequency components. The transform was carried out using 4-second Hann windows with a 75% overlap, specifically on channels O1 and O2.

The expected result of the spectrogram in the occipital region is the presence of amplitude peaks at the same frequencies as the visual stimulus, including its harmonics, as exemplified in Figure 3. These peaks are indicative of specific responses to the visual stimulus and also serve to validate the proper equipment configuration and the integrity of the collected signal.

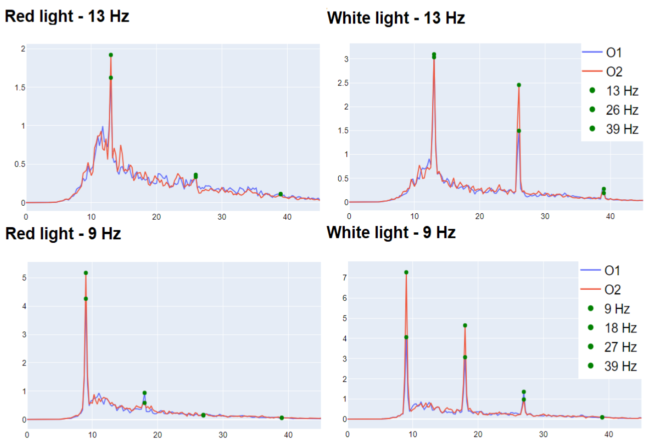

Fig. 3: Amplitude peaks in response to the visual stimulus of a flashing red and white LED at frequencies of 13 and 9 Hz.

V. Conclusion

This study demonstrates the integration of actiCHamp with OpenViBE, and provides practical considerations, enabling efficient EEG data acquisition in real-time. The validation of this integration was performed through SSVEP analysis, observing the presence of power peaks at the visual stimulus frequency and its harmonics, confirming the quality and reliability of the collected data.

This methodology can be used to develop more efficient and accuracy BMI. By combining EEG data acquisition with real-time interpretation and decoding through OpenViBE, it is possible to create systems that allow direct communication between the brain and external devices. This can have broad applications, such as assisting individuals with severe motor disabilities in controlling robotic prosthesis or other assistive devices. The detailed guide of this study can be considered a valuable resource for institutions and professionals who possess the actiCHamp.

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